TRAFFIC QUARTERLY

AN INDEPENDENT JOURNAL FOR BETTER TRAFFIC

APRIL 1956

Our Road Problem
The Interstate System
Urban Mass Transportation
Rating System for Rural Roads
Forecasting Zonal Traffic Volumes
Philadelphia Modernizes Signals
Seattle's New Parking Rates
Shopping Center Access
Sign Illumination

THE ENO FOUNDATION FOR HIGHWAY TRAFFIC CONTROL

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Our Road Problem

GOOD road-planning—good for the whole nation—receives heartening impetus from our changed attitude toward big problems.

In slightly more than a generation, we have fought two wars and a major "police action" in foreign lands. They were costly in lives and money, but the aftermath of the cataclysms brought a unifying new consciousness. We could not enter world wars without a nationally concerted effort. The ramifications of our problem focused our resourcefulness and our need to correlate the best thought of our best minds.

Our experience awakened our world-wide thinking, broadened our associations, and created new tasks. It required new skills and wider vision to meet conspicuous changes in our attitudes toward national problems.

Since World War II, we have made unparalleled progress in science, industry, health, and our general well-being. Many of these attainments stem from the wars.

Their dominant influence stimulated creative imagination, productive effort, and a fuller appreciation of our abundant life.

In the field of human interest and welfare, few advances through inventive genius have contributed so much as the improvement in communication, changes in time, and distance. These have brought a degree of solidarity and reciprocal relations that otherwise we might never have known. The imponderable benefits of rapid, efficient transportation of food, supplies, and people cannot be overemphasized.

Throughout our history, it has been doctrinal that good roads are good for the country. Efforts to provide them have been accompanied by clamor for special interests resulting in postponement and defeat of their recognized purpose. Repeatedly such restricted and limited progress has been a disappointment to public thought and interest.

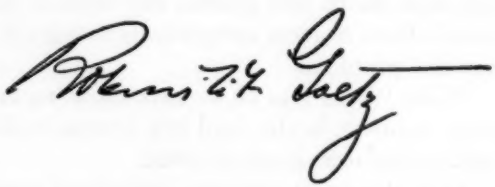
Again we are debating ways and means to mend our past omissions. During our long lag in providing timely measures for appropriate road building programs, automotive transportation has far

outstripped good roads. This adds to the urgency of expert and unbiased planning, consistent with our pressing needs.

Suitable financing is appurtenant to making good programs but we should not be frustrated by minutiae. One look at the character and mileage of our automotive transportation should provide a convincing estimate of the public's interest in and anxiety for more and better roads.

In seeking the most from our advantages in climate, terrain, and resources, and the unification of our people, we should not again be diverted by partisan interests, or half-hearted measures.

We need improved roads, efficient travel on them, and the maximum use of modern transportation. They provide our best approach to better living, better understanding, and continued economic growth.



The Interstate System

A. E. JOHNSON

Mr. Johnson is Executive Secretary of the American Association of State Highway Officials. From 1927 to 1955, he worked for the Arkansas State Highway Department, from rodman through designer and research engineer to Chief Engineer. In 1954, he served as president of the AASHO, and in 1955 became Executive Secretary of the organization. He is a member of the American Society of Civil Engineers and of the Institute of Traffic Engineers. In 1952, he received the AASHO 25-Year Merit Award.

THE importance of the 40,000-mile interstate system of highways is assuming added significance constantly with public realization that traffic demands are far outdistancing available highway facilities.

Probably the most effective way to introduce the public to the safety, convenience, and economy of modern highways is to construct the vitally needed interstate system. Such action would provide a sample of modern highways in every state, and modern highways are their own best salesmen. The interstate system—a limited-mileage, nationwide network of arterial highways basic for an expanding economy and for enhancing the country's ability to defend itself from without—could spark a future road and street modernization on all systems and at all levels of government.

With the evidences of increasing interest in an enlarged highway program at the public and public official levels, as well as in industry basic to our way of life, one must realize that problems of the greatest magnitude must be considered. Answers must be found posthaste. Such a program will be authorized, and the highway industry and the engineer must be ready.

If the network is not constructed on proper locations to adequate standards, designed for future traffic and operated commensurate with modern traffic demands, the net result would be an additional mileage of functionally obsolete highways. Functionally obsolete highways, either from the viewpoint of traffic capacity or other geometric features, can never be safe highways.

Answers to the question as to what constitutes proper locations, design standards, and future traffic needs must be found and used with imaginative, yet not extravagant, foresight to prevent spending unprecedented amounts of the nation's resources on what could be the biggest engineering blunder in history.

The interstate system must be located, designed, constructed, and operated in the earliest possible time to serve the traffic needs of present and future. And it must not be "too little and too late."

A word of admonishment is also in order—a balanced program of orderly highway improvement on all systems, commensurate with the most pressing needs, is a necessity. Local roads, state highways, or city streets must not take a back seat. However, accelerated modernization programs on these facilities should probably surrender to a stepped-up program on the interstate network, since the modernization of the interstate, rural and urban, will automatically lessen or eliminate the most pressing traffic bottlenecks and permit the evacuation of the metropolitan areas in case there is the threat of thermo-nuclear attack.

The Interstate System

Much has been said of the interstate system, and much more is due to be said in the near future. It is a 40,000-mile system of arterial routes, nationwide in coverage, that is 1½ percent of our 3,366,000-mile public road system. It joins more than 90 percent of all cities of 50,000 population or over and serves forty-two of the state capitals. The interstate system is now a series of termini and control points. When constructed, a large percentage will likely be on new location. Existing routes connecting the various termini and control points carry 14 percent of all motor travel. When the system is completed, it is not unreasonable to expect it will accommodate at least 25 percent of the total traffic.

Practically all the expanded road proposals considered by the 84th Congress emphasize the construction of the interstate system to standards to meet the traffic demands of some twenty years hence. Only by the program's being authorized at the national level, and priority treatment's being provided by the considered 90 percent federal and 10 percent state financing proposals will a national

system of modern defense highways ever become a connected and integrated usable traffic entity. Such a system will never become a reality if it must be authorized and constructed simultaneously at the several state levels. The states are aware of the importance of a national network of modern highways, but must give primary consideration to furnishing roads of more importance and popularity at the local level with the modest budgets available to the majority of the states.

It is also unlikely that the several states would take action to increase user taxes to finance a connected national network, and unless the action were unanimous, a completed nationwide modern highway program, needed for an expanding economy and for defense, would not be obtained.

The history of the development and designation of the 40,000-mile interstate system is of interest. The Congress, after giving considerable thought to the need for a "few transcontinental superhighways" across the United States, requested the Bureau of Public Roads to make a study of the need and desirability. As a result, the Congress in 1944 authorized the designation of a 40,000-mile system of highways to connect as directly as practicable the principal metropolitan areas and industrial centers, to serve the national defense, and to connect with the routes of continental importance in Canada and Mexico.

In 1947, the major control points were established by the joint action of the several state highway departments, the Bureau of Public Roads and the Department of Defense. The mileage measured along existing routes connecting control points, which was mostly rural in character, totalled 37,700 miles, leaving some 2,300 miles of the authorized 40,000 miles reserved for urban circumferentials, radials, by-passes, connections, etc. The 2,300 miles have been designated by the Bureau of Public Roads in recent weeks.

The 1952 Federal Aid Highway Act provided a token allotment of $25 million a year to the interstate system, or about one-tenth of one percent of the cost of building the network to adequate standards.

In 1954 the federal aid for interstate system routes was increased to $175 million a year to be matched on a 60 percent federal and 40 percent state basis. On the basis of the combined state and federal

funds for the interstate system as encompassed in the 1954 Highway Act, it would require approximately 100 years to build this important defense network to the traffic requirements estimated to exist only some twenty years hence.

Since only 8 percent of the interstate system is constructed to adequate standards, it is evident that "business as usual" will not supply vitally needed highways and the penalty for failure is jeopardy of our national freedom and the stifling of our way of life and economy.

Needs and the Price Tag

Section 13 of the Federal Aid Highway Act of 1954 requested the Bureau of Public Roads to estimate the needs on the nation's complete highway, road and street mileage under the jurisdiction of 35,000 units of government.

The state highway departments gathered the necessary data and the findings were made public by the Clay committee in January of 1955. The estimate was based on constructing the 40,000-mile Interstate System to meet the anticipated traffic demands of 1975 and for improving the balance of all roads and streets, totalling some 3,325,000 miles, on the basis of reconstructing those facilities that will wear out or become obsolete before 1965.

The Clay committee, a fact finding group appointed by President Eisenhower, recommended that the federal government finance 90 percent of the cost of construction and right of way of the interstate portion and continue aid to the other federal-aid systems, which would make the federal government during the ten-year period supply 30 percent of the total $101 billion price tag on our road needs. The committee recommended a federal expenditure of $25 billion on the interstate, or more than twice the total of all federal road aid in all categories since the Federal Aid Highway Act of 1916.

The Clay group found that on the basis of current highway funds only about half the $101 billion needs would be available within the next ten-year period. The committee did not propose the $101 billion figure as a program, nor did it make any recommendations on how the balance of 70 percent of the $101 billion, that would be the state and local responsibility, might be supplied.

The Clay report showed the close relationship that exists between motor-vehicle travel and the gross national product.

The fact that many persons gathered the mistaken impression that the $101 billion needs figure was being proposed as an ambitious highway program confused the problem. The total figure is astronomical in the light of our past concept of highway expenditure. Yet when considered in the light of the effect of needed roads on the future, the economic gains to be derived from adequate and safe roads, the figure is not astronomical in comparison.

Can the Nation Afford Modern Highways?

The Clay committee reported that adequate highways can cut the operating cost on the composite motor-vehicle one cent per mile, which at the present rate of travel would amount to $6 billion annually.

The public road and street system, as it now exists is, with some few notable exceptions, the same system that was in service prior to World War II.

Generally the primary highway system was delineated and constructed three decades ago when there were only one-third the 61 million motor vehicles in use, and they were traveling at half the average speeds.

The secondary land-service and trade territory roads and the majority of city streets generally are older than the nation's primary highway network.

Three factors cause highway functional obsolescence; speed, traffic density, and vehicle size and weight. Tremendous increases have occurred in all three factors.

Roads constructed at this time must be wider and thicker, and have flatter grades and better alignment than the average existing highway, and, consequently, are more costly to construct.

Excessive tire wear, excessive fuel and lubricant consumption, vehicle depreciation, time loss, damaged produce, health hazard, property damage, personal injury, loss of earnings for the injured, and the inexcusably high highway human death toll are tangible items to be considered by the economist or the average citizen when debating whether the nation can afford improved highways.

In 1955, the traveling public spent more on motor insurance premiums than was spent on highway capital improvements. Motor-vehicle accidents cost this nation in excess of $4.5 billion, with excess operating costs and time losses difficult to estimate, but probably in the vicinity of $6 billion annually. Nearly 40,000 persons are killed annually in motor accidents—which constitutes a terrific economic loss, as does the 1¼ million personal injuries, resulting in 100,000 persons a year being left with permanent impairments.

Dollar value cannot be placed upon a human life lost nor on national freedom. The civil and the national defense aspects of an integrated system of modern highways connecting population centers could easily be worth the price of the highway network itself.

Yes, it is costing too much not to buy adequate and safe highways. It is significant that in 1955 there was an increase in motor travel of 4.6 percent over 1954 and a 7 percent increase in fatalities. This could indicate what to expect in the future if highway facilities are not improved.

The cost of not having proper highways will increase as a geometric ratio.

Access Control—What and Why?

Access control is progress in motor transportation and its application is a necessity on the interstate system. The lack of access control can cut the traffic capacity of a highway by one-half and increase the accident rate as much as five-fold.

Access control preserves the investment in the highway, as well as its location, and in many places, logical highway locations are being rapidly exhausted and literally "consumed."

Until the present, road authorities have been called upon to furnish two classes of highways. First, the local road, the land-service road, the trade territory radial, designed and constructed to serve the land and improvements through which it traverses. An all weather and preferably a dustless surface is desired, but generally the traffic is light and this class of road is the least expensive per unit length to construct. In this case, design standards should be kept low enough to be adequate because of the light traffic and extensive mileage.

Second, the primary or trunkline highway which has functioned as a dual purpose facility, accommodating the long haul through motor travel, as well as serving adjacent property. When certain traffic densities are reached, the two services are not compatible. Efficiency and safety are sacrificed.

The time has arrived in motor transportation requirements for the third class of road, a controlled access, multilane divided highway located, designed and operated for efficient, convenient and safe express motor travel along lines connecting the major traffic generating areas. In this case, the design standards must be kept high enough to be adequate because of the heavy traffic densities and the need for furnishing maximum comfort, efficiency and safety on a limited mileage network.

The acceptance and popularity of the toll turnpike prove the contention that a limited mileage of such highways is definitely needed. The major items purchased by the toll turnpike patron are the conveniences and safety features afforded by access control.

In case the interstate system should be called upon to serve in a civilian defense crisis, access-control features would prove invaluable, since the facility would carry the maximum lane capacities in the most orderly fashion possible under conditions of panic and when only a minimum of policing might be available.

Much opposition must be expected locally and politically when a major construction program using the access control concept is launched. It will require considerable fortitude on the part of the highway official to proceed with the needed design in the face of such pressure, but it must be done if the interstate system construction is to be adequate and the investment insured.

What Will be the Design Traffic?

If the interstate network is to be constructed to accommodate the traffic expected twenty years hence, it is important that the probable traffic demands of that period be known reasonably close, especially in light of the amount of money for constructing the system.

At present some ten percent of all urban and over twenty percent of all rural motor travel is on the existing roads and streets connecting the interstate system control points.

One might assume that an expected annual compounded traffic increase of 3 or 4 percent might be applied to the present traffic and thus arrive at a logical and satisfactory answer for twenty years from now.

To follow such a procedure is the height of folly. Much has been learned of induced traffic on modern thoroughfares and much remains to be learned.

Urban traffic is becoming strangled; local road travel is increasing at a much lesser rate than for the trunkline. A real and dynamic urbanization migration is in progress, increasing traffic needs through, between and outside cities.

Many persons avoid long motor trips when possible because of the tension of driving, the time required and the accident exposure.

Major population centers are not now generally connected by safe modern highways, but may have two or more functionally obsolete routes connecting the same general termini and traffic deploys over the several available facilities that would all gravitate to a modern turnpike if one were available.

Experience has indicated that controlled access modern highways promote improved land use, industrial development and housing along the route, thereby generating traffic, in addition to the normal expected increases.

Considering that urban traffic needs are bursting at the seams, that urbanization is compounding and complicating the picture, that normal and created generated traffic increases must be recognized, and that most all long haul travel will concentrate on the rural interstate routes, much time, study and vision should accompany the determination of the expected travel of twenty years from now. The design of the facilities should not only accommodate that traffic, but should be such that modification can be made to further the traffic within a reasonable future thereafter, where practicable, for the traffic demands of this nation will never be static as of a given date.

Design Standards and Locations

In determining the location of any section of the interstate network, a complete analysis is justified and indicated.

Comprehensive origin and destination studies are a necessity in and adjacent to urban areas to develop the desire lines to aid in locating facilities where they will furnish the maximum of utility. To arrive at the final location, the route thus indicated must be tempered with the economics of the cost of construction, the cost of rights of way and the effects and limitations of physical features of the general area. In other words, the adopted alignment is a compromise of these items, keeping as close to traffic travel desires as is economically and physically possible.

In rural areas, the matter of direct and improved alignment versus circuitous travel could be an item of economics to be considered. In the main, the major problem in locating the interstate system routes in the rural areas will be whether to improve and modernize existing routes or to construct on new locations with the present roads serving as collecting and distributing routes, as well as furnishing local service.

A minimum of frontage road construction should be considered when constructing a new location, it being used only to repair severed existing local road systems or to serve property that might be isolated by the construction on new locations. There is no excuse for adding the expense of frontage roads along new locations as a policy matter for they may later serve to complicate operation and policing by encouraging ribbon development on the frontage roads along the throughways.

In acquiring the necessary rights of way for interstate routes, or new locations, the property owners should be paid a fair price for land, the improvements and for severance damages, but to enhance the property by furnishing publicly financed and maintained frontage roads would be additional compensation in the form of a windfall to which the property owner is not entitled and for which the public should not have to pay.

When existing routes are modernized, many features should be considered, such as access rights, extensive frontage road systems, utility relocations, large amounts of improved real estate, and the salvage value of the present facility as to how it might fit geometrically and structurally into the needed design, whether the existing pavement be used as a frontage road or as a throughway.

The route location should be studied between major control

points at one time and no contract awarded for the construction of a section of the route until the exact location of the whole route between the major control points is determined and the applicable design standards to be used on the entire construction program are agreed upon by all cooperating agencies involved in the interstate system program.

The design standards should vary for various traffic densities, topography and influence—urban or rural. If the design standards are not uniform for the entire program, then the first increments could be obsolete when compared with the last portions of the program completed.

To develop standards, uniformity from state to state is of paramount importance. It is only basic that the size and weight of the design commercial vehicle be known and be controlled, unless the whole road investment be made obsolete with the manufacture and use of larger vehicles.

The design vehicle size and weight should be determined by objective and thorough study so as to obtain an optimum balance between the most efficient road use and most economical road life, all based on the nation's economic ability to furnish motor facilities.

Interstate design standards should be such as to provide the maximum safety that can be reasonably designed by the engineer and insure convenient and comfortable express travel. They must not be wasteful, but they must be adequate.

Access control must be provided initially in all routes, except in the sparsely settled regions. There some direct access must be allowed where the entering or cross traffic is of sufficient amount to create tangible hazard, but design and right of way acquisition on these routes should be such that, if in the future, land use changes or population shifts should make access control desirable, it can be established.

Over the years, the extremely modest budgets available to the highway officials have created a severe and ultra-conservative viewpoint as to "the standards that the public can afford." The public is realizing that half-way measures are neither cheap nor safe, and the highway official must realize that he must be a leader with vision and design what is needed on the limited mileage interstate system. Some few highway officials may believe it politically expedient in

their individual cases to oppose access control and modern design standards. Others will conscientiously believe the country does not need such modern roads, but these men have failed to progress with the needs and are giving no thought to the expanding economy, the technological advance in the motor car, the need for safer roads, nor the defense aspects.

Study of Existing Facilities Indicated

When the interstate construction program is authorized, all the state highway departments will be in the business of designing rural and urban modern controlled access highways at once. Some may have had little or no experience in this field. Much of the past experience has been in modest improvements in existing roads and streets. There could be a "too literal or too mechanical" use of the applicable design standards by the novice, resulting in some functionally obsolete facilities difficult and expensive to operate, and hazardous for the user.

Such a possibility must be avoided in every instance. It is important that all designers connected with the program inform themselves on the proper use of design details to the maximum degree.

Several states have pioneered in the design and construction of urban freeways and rural expressways. Some mistakes have been made and many desirable features have been created. A thorough study and analysis of the functioning of all such existing facilities should be made and the results made known to all concerned.

If design features have proved inferior or faulty, they should be avoided. If operation indicates that certain design details could be improved, this should be known. There is much to be learned regarding operation and traffic control, especially on freeways. The project planning cannot stop at the right of way lines and the facility be functional. The exit ramps must discharge into facilities that are capable of efficient dispersal and not into already over-crowded arterial streets.

Weaving distances must be adequate and these distances vary geometrically with average speeds and the number of traffic lanes. If a facility is so crowded that all lanes are filled solidly with moving traffic, then even extremely long weaving distances are to little avail,

for the motorist cannot change lanes to get to his exit point. Study is needed on the maximum frequency of interchanges wherein excessive traffic turbulence will not be created, as well as on what type of interchange works most effectively under traffic for various conditions.

Much study has been undertaken on the readjustment of area traffic patterns and practices with the introduction of freeways and much more is needed.

Thorough study on an individual project basis is needed to insure that sections of urban freeways, built as stage construction, will be usable and functionable increments and will blend in with the existing street system.

More studies are needed as to the economic effects of access controlled expressways upon the area, as well as to the decrease in fatalities and accidents caused by access control, full and partial.

As many additional studies as possible should be made as to the economic effects upon a community because of being by-passed, and the results of all studies should be made available to all concerned with administering and designing an accelerated road program.

Those employed in the highway field know the answers within a reasonable degree, but there is not enough evidence existing to convince the recalcitrant politician, the local business man, or the property owner, and all the factual data and evidence that can be assembled will be needed to sell the interstate program at the local level.

Over-crowded or functionally obsolete highways can never be safe highways, and inadequate and hazardous highways are a luxury that America cannot afford. Public opinion will give a mandate to correct the nation's highway deficiencies, and at that moment the highway official must be ready to perform the task with distinction and with competence. His performance must be predicated upon objective factual study, upon economic determination, and upon vision.

Above all, he must not waste the public substance nor his opportunity upon a mass of contemporary obsolescence neither adequate nor safe. He must remember that no highway can be said to have been over-designed to date. In fact, most facilities have reached full capacity far ahead of expectations.

Suburban Shopping Center Effects On Highways and Parking

HOMER HOYT

Dr. Hoyt for the last decade has been president of Homer Hoyt Associates, consulting land economists. Previously he was Director of Economic Studies for the Regional Plan Association of New York; Director of Research for the Chicago Plan Commission, and principal Housing Economist for the Federal Housing Administration. He served as Associate Professor of Economics at the University of Missouri and at the University of North Carolina. He is author of several books and articles on land values. He is also a member of the bar.

THE new type of suburban shopping center is a product of the automobile and the concrete highway, even as the old retail structure was the product of mass transportation. Catering to customers who come chiefly by automobile, the new centers must be located at access highways on tracts of land large enough to provide a belt of parking in front and sometimes on all sides of the shops.

In the retail pattern dominant before World War II, stores were built solidly to the sidewalk line to get as close as possible to customers alighting from street cars, buses, subways, elevated lines or suburban trains. The major pre-war centers were situated at focal points of mass transportation; in central business districts where subways, street cars or suburban railroads converged, or at outlying street car intersections. And at these strategic places there was a concentration of large department stores, apparel and other fashion goods stores.

Prior to 1929 most of the urban population lived within walking distance of a street car line, subway or elevated station or suburban railway station, and these transportation media conveyed shoppers either to local convenience stores beyond walking distance or to central shopping districts. The revival of building after the depression following 1929 started a tremendous movement of population away from mass transit lines into areas where most families depend mainly upon the private automobile for transportation.

In the last nine years, ten million non-farm dwelling units have been constructed in the United States; of these units, approximately seven million were built outside the corporate limits of all cities of 50,000 or more population, and a considerable proportion of the remaining three million were on the outer edges of the cities. These seven million families who have established new homes outside central cities in the last nine years and who use automobiles in shopping, have aggregate annual income of more than $50 billion and they spend $30 billion in retail stores. This market, growing at the rate of nearly a million families a year, has created the opportunity for the new style shopping center.

The impact of these new centers on highways and traffic depends upon the size of the center, which in turn depends upon the territory it serves. Shopping centers may be classified into four types:[1]

The Large Regional Shopping Center

This largest type center contains at least one large department store of 125,000 to 500,000 square feet—sometimes two department stores —and has a representative group of women's and men's clothing, shoe, variety, drug, and furniture stores, as well as supermarkets and other local convenience stores.

The total store area ranges from 500,000 to 1,000,000 square feet; the total land area in the shopping center from fifty to one hundred acres. Car parking spaces number from 2,500 to 8,000. This regional shopping center offers almost as wide a selection of merchandise in apparel lines as the central business district. It requires a population of 250,000 to 1,000,000 in the one segment of a metropolitan area constituting the trade area, to support a full-scale regional center.

The large population required to support them definitely limits the number of large regional shopping centers that can be built in the United States. At the present time, at least twenty-four large regional shopping centers of 500,000 to 1,000,000 square feet of store area each—a total of 18,000,000 square feet of store area—have either been built, are under construction, or have definite commitments for major leases and financing.

[1] Urban Land. April 1953. Vol. 12, No. 4.

The Class II center contains a junior department store of 40,000 to 80,000 square feet as its largest unit. It has a large variety store, women's and men's clothing stores, shoe stores, supermarkets and drug store, and local convenience stores. The Class II center has a total store area of 150,000 to 200,000 square feet on a land area of twenty to forty acres, and requires a population of approximately 100,000 in its trade area to support it. There are probably more than 100 of these medium size centers either in operation or definitely committed for construction.

Classes III and IV

A Class III center is one in which a variety store is the largest unit; it also contains supermarkets, a drug store and local convenience stores. The total store area of this center would range from 50,000 to 100,000 square feet, and the land area from five to ten acres. It would require 10,000 to 15,000 families or 30,000 to 50,000 people in its trade area to support such a center.

In a Class IV center the supermarket is the largest unit. Since families spend an average of at least $1,000 annually for food, 2,000 to 3,000 families or 7,000 to 10,000 persons would support this type of center. In addition to the supermarket are a drug store, hardware store, beauty shop, cleaning and pressing shop and other local convenience shops. The total area of stores would range from 20,000 to 40,000 square feet, and the land area from two to five acres for this type of shopping center.

There are of course numerous hybrids in addition to the main types, such as the solitary department store with few or no other stores nearby, or at the other extreme, large local convenience centers with several supermarkets and variety stores, but with no department store. Many urban regions have their own unique retail pattern which has become established and cannot easily be changed. These main types, however, will serve to show the effect of differences in shopping center size upon the highway pattern.

Large Centers Need Access

The largest regional centers, drawing their customers from a wide radius, must have access to major highways and provide facilities

not only for parking 5,000 or more automobiles at one time, but also for their circulation within the center and for their entrance and egress in a short period of time. It is not necessary and may not even be preferable to locate these centers at interchanges on expressways; but they should be located near, if not directly at an intersection with a major radial and a belt highway.

The Cross County Center in Yonkers, New York, one of the largest, with Wanamaker and Gimbel department stores, has 1,000,000 square feet of store area on sixty-five acres. It is situated at the intersection of Central Avenue and the Cross County Parkway—the expressway leading from New York to Connecticut and New England. Access from the parkway is by a side road two blocks from the main center. The Cross County Parkway intersects north and south radial highways leading into New York City through Westchester County, including the new Thruway.

The 1,000,000 square foot Northland Center in Detroit, with its J. L. Hudson Company's large department store, has access from the Northwest Highway, an expressway on the west, and Greenfield on the east, with the 8 Mile Road to the north. The Old Orchard Shopping Center north of Chicago at Skokie and Golf Roads comprises seventy-five acres now under construction, with Marshall Field and The Fair department stores. It is near Edens Expressway, but a mile away from the interchange. It is an advantage for a shopping center to be away from the congestion at the point of interchange, but still accessible by side roads to the expressway.

On the other hand, Edens Plaza in Wilmette, north of Chicago, with a 120,000 square foot Carson Pirie, Scott and Company department store, is situated at the interchange on Edens Expressway. Evergreen Plaza in Chicago, with two department stores, is at the intersection of 95th Street and Western Avenue; neither is an expressway.

Swifton Center in Cincinnati, with Rollman's Department Store (Allied), is situated at the intersection of Reading Road and Seymour, both major arteries. The planned Bergen Mall Center with 1,700,000 square feet of store area, on Route 4 eight miles west of George Washington Bridge in Bergen County, New Jersey, contains 100 acres divided into three parcels by the highways, with numerous local access roads to the main section.

Aerial view of Northland Center showing parking facilities and highway connections.

Mayfair, the 900,000 square foot center on 100 acres in Milwaukee, where Marshall Field and Gimbel's will have large stores, is on Highway 100, the belt highway around Milwaukee. Gulfgate in Houston is an 850,000 square foot center with a large Joske department store, on the Gulf Freeway, near the interchange at Holmes Road. Shoppers' World in Framingham, Massachusetts, built around a large Jordan Marsh department store, is on Route 9, a main radial highway from Boston, but not on the belt highway.

Proposed Centers Plan for Access

Direct connections with an expressway are planned for Southland in Tulsa, Oklahoma and at the Blue Ridge Shopping Center east of Kansas City. The Belleview Shopping Center, planned for Oklahoma City, is at the intersection of Pennsylvania Avenue and the Northwest Highway which connects with the Turner Turnpike. Atlanta's Lenox Square Shopping Center will be on Peachtree Street, with numerous local access roads leading to the high-grade residential area and to the two prongs of the new expressway system.

The Ward Parkway Center in Kansas City will have Ward Parkway on the east—a high speed highway leading to downtown Kansas City—and the State Line Road on the west. The Seven Corners Shopping Center now under construction in Fairfax County, Virginia near Washington, D.C. with Woodward and Lothrop and Julius Garfinckel department stores, is near the intersection of major highways leading from Washington to northeast Virginia. The Parkington Center near Washington, D. C. with a 250,000 square foot Hecht department store, lies at the intersection of Wilson Boulevard and Glebe Road, the belt highway in Arlington County, Virginia.

Shopperstown in East Providence, Rhode Island is situated at the intersection of Route 44 and 1A, both major routes. The planned Allied Stores Corporation's Southland Center at Raynham, Massachusetts is on Route 44 just east of the intersection with the Fall River Expressway, but not immediately at the interchange.

One of the most ideal locations from a highway approach standpoint is the North Shore Center at Peabody, Massachusetts, which is being developed by Allied Stores Corporation with Jordan Marsh and Filene department stores. With 1,000,000 square feet of store

area in its initial plan, on a site of more than 100 acres, this center is on Route 128, the six-lane belt expressway around Boston with an interchange to Highway 114, a major artery from Salem to Peabody on the north, and to a highway on the south. Both of these lead to Route 1 on the west, the main expressway to New Hampshire and Maine.

These local highways between the two expressways are aptly termed "women's roads" because they are free from heavy congestion and minimize driving difficulties for women shoppers. This location is preferable to one at the intersection of Routes 1 and 128, where there would be a heavy interchange of through-traffic.

Not on Established Highway

Northgate in Seattle, owned by Allied Stores Corporation, is on a major highway and has good subsidiary access roads to all parts of its trade area. Some medium size regional centers—like Cameron Village in Raleigh, North Carolina—were not constructed on any existing main highway, but a new highway was built through them connecting with local streets. The Park Forest Center south of Chicago, with Marshall Field's and Goldblatt Brothers' 60,000 square foot stores, is not on a major highway but in the midst of a huge housing development.

Class II shopping centers, in which a junior department store is the leading unit, are frequently situated on main highways. The Village in Gary, Indiana is on Grant Street, a main street leading to the steel mills, a block north of the intersection with heavily traveled Route 6. This fact is considered an advantage because it avoids the congestion at the intersection.

The Miracle Mile in Pittsburgh is on the William Penn Highway near the intersection with the Pennsylvania Turnpike. Town and Country Center in Columbus, Ohio is on Broad Street—Route 40—the most heavily traveled east-west road. The Thruway Center near Buffalo adjoins major highways.

In contrast with the Class I or Class II center drawing shoppers from ten to fifty miles away, the Class III or IV center, with a variety store and supermarkets, can be located on local access roads, although even in these smaller centers a site on a major highway is often desirable.

In establishing a new shopping center, traffic engineers must calculate the extent to which the new center will increase the traffic flow on existing or proposed highways. In making the analysis of traffic, it is important to recognize the fact that the peak shopping traffic will occur in off-peak hours as far as travel from home to work is concerned. All of the new shopping centers are open every weekday evening and most of the sales are made in the afternoon and evening, from 2 to 4 P.M. and from 7 to 9 P.M.

Traffic Problems

In estimating the load imposed upon the highways, the traffic engineer must have a market survey which will show the current number of families in each segment of the trade area from which the new center will draw customers. This will enable him to estimate the amount of new traffic that will be generated on each of the highways leading to the center.

The traffic engineer, in addition to calculating the impact of the new center upon the highways leading to it, must also design the interior circulating roads within the shopping center, and as many entrances and exists as are feasible so that shoppers can leave in large numbers in a short time without creating undue congestion. The traffic design of a new regional shopping center is one of the most important factors in its successful operation because ease of parking and the facility with which the woman shopper can enter or leave the center constitute its greatest appeal.

The new expressways are having a far-reaching effect on the urban pattern that also reacts upon the shopping centers. Just as transcontinental railroad lines, designed for long-haul freight and passenger traffic, developed suburban railroad service in many metropolitan areas, new expressways cause a tremendous residential growth along their routes within metropolitan areas.

There has been a great surge of new home construction along the Calumet Expressway southeast of Chicago; along the William Penn Highway east of Pittsburgh; along the Pennsylvania Turnpike north of Philadelphia; along the Gulfgate Freeway in Houston and along many other new expressways, because of the speed with which workers in cars can travel from home to work along these limited access highways.

New industrial districts are being constructed also along the belt highways, such as Route 128 around Boston, so that the working places are brought closer to the home areas. This rapid growth of population along the expressways accelerates the growth of new shopping centers adjacent to these expressways.

The expressways have other long distance effects. A national food chain is establishing a large store in a new shopping center on Long Island because the new connection between the New Jersey Turnpike and the Pennsylvania Turnpike seventy miles south, will speed up deliveries of food from Pennsylvania to Long Island.

While the toll roads will thus speed up long-distance hauls, the shopping centers will benefit most from location on freeways or limited access roads without any toll, since even a small charge on a toll road, even as a small parking fee, has some deterrent effect on shoppers.

The close relationship between the highway pattern and the character of highways with the new shopping centers, new residential developments and new industrial locations makes it necessary for traffic engineers to consult with city and regional planners and with urban economists to obtain an integrated regional plan beneficial to the entire community.

The new type of shopping center is usually located by developers where a sufficiently large tract of vacant land under one or only a few ownerships can be acquired at reasonable cost, for which commercial zoning can be obtained. There need to be a sufficiently large trade area to support the center, and leases from national chain stores. If a number of such locations are available in a region, the one with the best highway access and the one imposing the least burden on existing traffic loads might be selected.

The site finally chosen however, may not be best from a traffic standpoint, but after it is constructed the highway pattern or traffic load must be adjusted to it, or made to endure it whatever the consequences. In future master plans of urban regions, suitable locations for the different types of shopping centers might be suggested in areas where the land is still vacant. These sites would conform to the master plan of highways and also of future residential and industrial development.

To make such a plan, it would be necessary to take into account

all existing commercial developments and to estimate future commercial requirements on the basis of anticipated growth in population and income of each segment of the metropolitan area.

Such foresighted planning would require cooperation between traffic engineers, regional planners and urban land economists. Each has special skills needed in reaching the best solution of the problem and in developing a master plan to bring into existence a more efficient urban pattern.

Urban Mass Transportation

GEORGE W. ANDERSON

Mr. Anderson became executive vice president of the American Transit Association in March, 1953. He joined the organization in 1944 after wide experience in the transportation industry as supervisor of motor vehicles for the Illinois Commerce Commission for eight years and as an official of National City Lines. During World War II, he served as Office of Defense Transportation regional assistant in charge of the New York and Boston field offices, and later became regional director, Division of Local Transport, O.D.T. Region 2, with headquarters in Philadelphia.

AFTER a decade of almost single-handed crusading—to save not only itself but also the central business districts it originally helped shape in America's cities—urban mass transportation is beginning to emerge from the isolation ward of municipal planning.

An unmistakable trend is developing toward meaningful recognition of transit's essentiality, especially downtown. This is most heartening to the transit systems—both those publicly owned and the private enterprises—which have waged a ceaseless postwar battle for restoring better balance between the use of public and private transportation on ever-more crowded city streets. By their actions, as well as in their public utterances, municipal and regulatory officials, business and professional men, and merchants and traffic engineers manifest a growing awareness that:

> It is people, not vehicles, that must be moved downtown to do the thousand and one things that must be done every day if the city is to remain a city.

Nashville and Toledo offer new and convincing evidence of how cities and transit systems can cooperate. In the Tennessee city, movement of all vehicular traffic was speeded up appreciably beginning with the first of this year: the municipality introduced exclusive lanes for buses on long sections of three key one-way streets leading to and from Memorial Square in the downtown district. To take full advantage of this national "first," the Nashville Transit Company rerouted more than thirty of its lines so that all lines serving

downtown would operate in a clock-wise direction around the square.

Shelters for bus patrons were built by the city around the square with funds especially earmarked for that purpose from taxes collected from bus patrons through levies against the transit company. These shelters were opened at the same time that the municipality set aside the curb lanes for exclusive use of the transit vehicles. Loading and unloading of passengers were speeded up materially; traffic moved more freely, and the city cooperated fully by enforcing its decree rigidly. Neon signs overhead warned motorists to keep out of the bus lanes. No parking was allowed on the streets, and violators faced tow-away charges in addition to fines.

In Toledo, traffic likewise was accelerated when the Community Traction Company instituted a free area downtown, with no fares collected from passengers entering and leaving within a 23-square-block area. At the same time, the city removed 338 parking meters, prohibiting all-day parking in a 12-square-block area and restricted parking during rush hours along main thoroughfares carrying traffic to and from the business district.

Benefits to Patrons and Industry

If this trend continues—and increasing traffic congestion forecasts it must—beneficial effects will be felt by more than the transit industry. True, the resulting stabilization will be of great value to an industry long called sick because it is undergoing a depression of its own in the midst of unprecedented prosperity.

More valuable however, will be the results accruing to that industry's patrons—those who ride transit, whether by choice or from economic necessity. For them it will mean an end to the vicious circle of paying higher and higher fares for a slower and slower ride in vehicles they have had to wait for longer and longer.

Even the motorist—who has been accorded what amounts to a rating higher than that of "Citizen, First Class"—will benefit. He will find it easier to travel in streets where more people are transported in fewer vehicles.

But transit still is a long way from the stability it needs, and which the communities it serves also need. Only the first phase of its

endeavor to enlist the public support it must have to do a better job has been completed. Only thoughtful leaders—those whose interests transit has succeeded in identifying with its own—are aware of the inseparable relationship between healthy, economically-sound transit systems and the well-being of the entire community.

Next, transit faces another big step. Having established the why of its importance, among community leaders at least, it must now achieve understanding and acceptance of the what and how of its willingness and ability to serve. It must demonstrate what it can do to alleviate traffic congestion, and how. It must present specific plans —on a street-by-street and route-by-route basis—for cities to use transit constructively as a positive tool to unsnarl vehicular traffic.

This step will be no easier than the first. But this utility, whose long and proud tradition of public service has enabled it to remain remarkably active and energetic even while being called sick, continues to be the liveliest force in most cities in pointing out traffic congestion's harmful effects on *all* business. It faces up to its new task and responsibilities with high hope.

Transit Regulations Outmoded

The source of that hope is that every day new community elements acknowledge that:

Traffic jams are at the root of central city disintegration.

Solving the traffic congestion problem hinges on solution of the transit problem.

The same virus—traffic congestion—which has made transit sick also has been undermining and enfeebling the entire community, causing disintegration of downtown districts, diffusion of major tax sources, and disruption of whole municipal economies.

Transit may be sick, but it cannot be isolated by the community.

Transit may be sick, but it cannot die.

The community simply cannot permit it to die.

Unfortunately, acceptance of these basic facts is by no means universal. In many cities, transit still is the political football it was back in the horsecar days, when it was a monopoly and the principal user of city streets for vehicular traffic.

The evolution of some 60,000,000 competitors has not out-

weighed the politician's inclination to continue trying to obtain from the transit company taxes largely unrelated to net earnings and which are not paid by other competitive businesses. Nor do these taxes take into account the economical use of scarce street space by transit and its riders as against the extravagance of individualized transportation in which the private automobile has become by far the principal user of the streets. Similarly, there remain in force regulatory processes and policies which long since have become outmoded. Like the gross receipts taxes and other special imposts, they are incompatible with competitive enterprise.

Both the taxes and the excessive regulation restrict the transit industry, especially as to experimentation with fares and service. But even worse, they pile onto the transit rider inconvenience upon aggravating inconvenience and cost upon burdensome cost. For in transit as in all other business it is the consumer who ultimately must foot the bill.

These policies and practices reflect the failure of cities and states to think in terms of people. Their retention reflects also the failure of subdivisions of government to recognize the full extent of the damage done by traffic congestion—to whole communities, but especially to transit and its riders.

There has been a tendency to regard the transit service as something apart and unrelated to the traffic congestion problem, to ignore the simple and obvious fact that traffic congestion stems from the enormous shift from public to private transportation since the end of World War II. The jungle-like battle for street space required by individualized transportation has been permitted to develop virtually without restriction. In fact, it can truthfully be said that cities have not only created, but actually have subsidized their traffic jams. For unwelcome though they may be, traffic jams are bound to result when public money is used almost without limit to alter entire areas for the greater use of streets by automobiles while public transportation is left to fend for itself.

Congestion Versus Convenience

It is paradoxical that we Americans, priding ourselves on our efficiency, persist in using the least efficient means of transportation in

congested areas. It is ironic that the private automobile, the most prominent evidence of our mass production genius, is undermining the urban civilization which created it. It is ironic that in pursuit of convenience we should take a couple of tons of steel, glass and rubber with us wherever we go, thus producing the inconvenience we all suffer in traffic congestion.

There is no question about the motorist's right to use the streets. The question is: Does one citizen have any more right to use the streets than another? A transit passenger occupies only about six square feet of street space, while the average automobile rider requires about ten times as much of that scarce commodity. It works out this way: One transit vehicle, with fifty seated passengers, uses only as much space as three automobiles which, on the average, carry one and one-half persons in each car.

Yet the municipality does not even treat these two types of citizens on an equal basis. Against the transit passenger, who asks no street widening, no expressway construction, and who needs no parking facilities, the city levies special taxes. In some instances, these amounted to as much as ten cents of every dollar he spent in fares. For the automobile rider, who does require all these improvements, the city spends the money thus collected—and then some.

The extent of subsidizing the motorist varies from city to city. Most cities have not even computed it. In Milwaukee, however, the city comptroller testified at a public hearing that the city spent $90 a year more on services to each of its motorists than the car owners paid to the city in taxes.

Like the amount of such subsidy, the people affected by traffic congestion have received scant consideration. Concern largely has been confined to moving still more cars through a given space or to increasing the space, regardless of cost—either in dollars spent on the particular improvement or in damage to the entire community in terms of business and tax sources lost to the suburbs.

This procedure has produced a narcotic effect. The greater the expenditures have been, the greater has become the need. With it all, no city can say, regardless of how much it has poured into providing convenience for its motorists, that it does not have far more congestion and far greater inconvenience today than when it embarked on its costly venture.

Traffic congestion, especially downtown, is more devastating than the mere inconveniencing of people in automobiles. Through the damage it does to transit—and that includes the passenger as well as the transit system—traffic congestion precipitates a chain reaction which is disastrous to the entire community.

Traffic congestion's relationship to transit operation is fairly obvious. First of all, the automobiles creating the congestion are carrying passengers transit once had and still could serve. In present-day numbers, these cars increase transit's costs through time losses incurred in the competition for street space.

Harmful Effects

What isn't so obvious is what this does to the rest of the city. As transit's product, the ride, is slowed down by congestion, passengers abandon it for their own cars. The congestion of course grows worse, and spreads the damage to other businesses as well. For as congestion grows worse, more and more people shun downtown. They refuse to brave the time-consuming, nerve-jangling traffic jams and refrain from entering the central business district, either by transit or in their own cars. The city's core loses business to places more readily accessible. Property values deteriorate in the municipality's highest land value area, and taxes to pay for vital city services must be shifted proportionately to the home owner.

This, then, is not merely a transit industry problem, nor one affecting only the financial well-being of those with money invested in the transit company. Traffic congestion affects everyone in the city. It is a community problem. Its solution is the responsibility of community leaders. Businessmen especially have a major responsibility, since they have the largest stake in restoring freedom of movement on streets giving access to their establishments.

Freedom of movement can be achieved by using fewer vehicles to transport more people into the compact central business areas. This feat can be performed by transit. That is why, in this automotive age, the transit industry's position has been: Not that automobiles should be banned but that their use should be governed so as to insure their maximum contribution to the community's welfare. It has asked the same consideration for transit vehicles. In other words, controls should be exercised to permit each type of vehicle

to do what it can best do in the community job of getting people into and out of congested areas.

What Cities Can Do to Help

In what people outside the transit industry are saying, and in some cases doing, transit operators find much hope. It is noteworthy that some cities are beginning to take stock of the results of past policies which have catered exclusively to the automobile. In some instances, communities are moving toward altering those policies to revitalize our downtown areas and to insure future metropolitan growth.

In Pittsburgh, for example, the City Bureau of Traffic Planning reports that in the last two years the increased use of automobiles has resulted in 11,000 more private vehicles downtown, but 17,500 fewer people in the traffic counts conducted. The report points out that the decrease in people making use of the downtown business district results primarily from the decrease in the number of trolleys and buses going into and out of the Golden Triangle, renovated at such great cost. The study reports a decrease in the number of trolleys between 1953 and 1955 from 6,100 to 4,623 per day, and a decrease in buses from 4,438 to 4,287 per day.

"The decline in the use of mass transportation and the increase in the use of private automobiles," states the report, "demonstrates that mass transportation must be made attractive from the standpoint of convenience and speed to retain the present transit rider or to regain some of those who have been lost."

This is the very crux of what heretofore has been called the transit industry's problem but which now is beginning to be recognized as a community problem: How to make mass transportation more attractive from the standpoint of convenience and speed. The sooner this problem is fully recognized and accepted as the community problem it really is, the sooner it will be solved. For transit, alone, cannot improve its service, cannot speed up the ride. It needs the help and cooperation of the community. Only the community can help free streets now clogged with private cars.

Another example of the growing awareness that transit brings more people downtown in fewer vehicles is provided in Baltimore. There, a citizens' Committee on Mass Transportation recently

FIGURE 1. In St. Louis, pennant designates express bus. Special bus stop designates express service, with time to downtown emphasized and time tables attached to sign post.

FIGURE 2. Rapid transit via buses on Los Angeles expressways and freeways, with turnouts provided for loading and unloading.

pointed up the extravagance of street space use by the private car in a report which showed a traffic count revealing "that one-third of all the people moving to and from the central area were carried on transit vehicles. Yet transit vehicles accounted for only two percent of all vehicular movement. Even more dramatically, during the rush hour one-half of the people are being moved by transit, while transit vehicles amount to just three percent of all vehicles on the street. The importance of transit in moving people is undeniable. Automobile traffic, by slowing transit movement, is steadily eroding the contribution that this form of transportation makes. In view of the magnitude of the service mass transit is capable of rendering, and to encourage an increase in the proportion of people using transit, efforts must be made to minimize the friction between the automobile and the transit vehicle."

The Baltimore committee then recommended vigorous study of the possibilities of separate lanes and even separate streets for transit, and also delved into the question of how to keep what it called nonessential traffic out of the central area by providing parking areas well outside the zone of congestion and connected to downtown by a system of fast, nonstop transit vehicles.

These measures—fringe parking and express service—long have been advocated by the transit industry as excellent methods of enabling the private car and public transportation to complement one another and, more importantly, enabling each to perform the role for which it is best suited in urban transportation. Transit has established express lines in many cities, both in connection with fringe parking and as a direct service from various residential areas to the downtown district.

Express Service in Many Cities

No one knows better than the transit operator that speed is the predominant factor in the passenger's decision for or against the use of transit. Express service, which is at least a partial answer to the demand for faster transit, is operating successfully in St. Louis, Cleveland, Atlanta, Cincinnati, Washington, D.C.; Chicago, Los Angeles, Syracuse, Philadelphia, Birmingham; Detroit, Pittsburgh, Memphis, San Francisco, Indianapolis; Louisville, Milwaukee, Min-

neapolis and St. Paul, and Vancouver, B.C., among other cities. The demand for this faster service is increasing, as evidenced in St. Louis where the service now is provided on eleven routes by 175 vehicles in contrast to the five lines originally served by forty-five buses when the service was initiated only a few years ago.

The popularity of the faster ride is attested by the willingness of passengers to pay the premium fare usually charged for it.

Under various names, fringe parking has been sparked by the transit industry in many cities. The following list by no means constitutes all the communities where transit is making a major contribution in keeping automobiles out of the city's center by serving motorists who prefer to avoid midcity traffic congestion, but it does indicate the scope of this service: Boston, Cleveland, Detroit, St. Louis, Atlanta; Miami, Providence, Baltimore, Chicago, Newark, Philadelphia, Pittsburgh; Dallas, Harrisburg, Toronto, Wilmington, Washington, D.C., and Richmond.

Besides making the fringe parking and express service recommendations, the Baltimore study made some significant comparisons with findings in 1934. These showed that vehicular movement downtown had increased by 75 percent, but the movement of people had increased by only 54 percent.

"This is explained," the report stated, "by the fact that transit vehicles carried about the same number of people in 1955 as they did in 1934, and is a measure of the inefficiency of the private auto as a mover of people in large volume. The importance of mass transit also is measured by the fact that two-thirds of the people who were downtown at the time of maximum accumulation of people in the area had come by transit. This remains unchanged from 1934, but the maximum accumulation of people in 1934 was higher by about 9,000 than in 1955."

In the words of a committee of its own citizens, that is what happened in one of America's principal cities. In a city in which the population increased by some 150,000 in the last two decades, fewer people are downtown today than twenty years ago. This is true in spite of the money people spent directly on automobiles for the convenience these vehicles were supposed to bring them, the efforts and tax money expended to widen streets and build freeways and expressways.

The futility of this approach becomes all the more appalling when we contemplate the sheer waste inherent in using as garages busy streets intended for the movement of people and goods and for the conduct of commerce so vital to our way of life. Additionally, there is the harm caused by destruction of buildings to make way for parking lots and parking garages in the central business districts of our cities. It is impossible to compute what it has cost us to tamper with the very compactness which makes people want to come downtown in the first place.

Other Cities Plan Studies

The foregoing excerpts from the Baltimore and Pittsburgh studies illustrate the concern being manifested in this problem. Many other cities have studies underway. Committees of citizens are interesting themselves. Some are appointed by the mayors. Others spring from chamber of commerce concern. Still others are named by city council action. Whatever their origin, it may safely be said that the need for such committees has been recognized largely because of the transit industry's insistence that traffic congestion is a community problem and not one which the transit industry should fight alone.

Data from various cities indicate the extent to which transit serves downtown and how important a partner it is in all central city business in bringing other businesses their customers and labor forces. It carries downtown from 30 to 80 percent of the people entering the central city area, even under today's highly individualized transportation conditions. More importantly, the data illustrate the efficiency with which transit moves these masses in a relative handful of vehicles and thus contributes to the alleviation of traffic congestion.

In Minneapolis, more than 42 percent of the people come downtown by transit in 2.77 percent of the total vehicles on the street. In Detroit, more than 47 percent of the people come downtown in just over 4 percent of all the vehicles on downtown streets. In Atlanta, nearly 60 percent of the people are carried downtown in 4.79 percent of the total number of vehicles.

Other studies show: In Atlanta, transit daily moves downtown 55.2 percent of all shoppers, 67.6 percent of all retail employees, 50

percent of all office workers, and 58 percent of all others. In Dallas, the figures are: 56 percent of shoppers, 70 percent of retail employees, 55 percent of office workers, and 30 percent of all others. In Omaha, the figures are: 66 percent of shoppers, 65 percent of retail employees, 55 percent of office workers, and 20 percent of all others. In Richmond, the figures are: 60 percent shoppers, 59 percent retail employees, 60 percent office workers, and 57 percent of all others.

Wherever thought has been devoted to the problem, the answer has been the same: Transit is so essential that communities must integrate it in their city planning. A few excerpts from speeches delivered before the September, 1955 Annual Meeting of the American Transit Association in Boston will serve to illustrate:

"There is really no good excuse for the situation," said William R. Marston, deputy city traffic engineer of the Chicago Bureau of Street Traffic, in discussing today's traffic congestion. "There is not a qualified traffic engineer anywhere that does not have all the information necessary to cure any traffic ailment. In fact, the traffic situation should not be called a problem. We know all the answers, so therefore no problem can exist. Expressways actually serve a very small part of the total transportation of a city. The local street system has long been called the stepchild of transportation in most cities, and yet it is here that pedestrians and automobiles mix in great numbers. Transit is no longer the business of a few stockholders—it is the business of the public and every city official. Someone will have to find a way to keep transit going unless the economy of our cities is to fall flat on its face."

Mr. Marston cited studies which, he said, make it "obvious that all persons wanting to travel could not, unless something other than private automobiles are used." This, he said, makes it clear that "within the next few years transit must in some way be made to carry a greater share of the travel burden."

Another transportation engineer, Hawley S. Simpson, in private practice in Philadelphia, expressed his views this way: "No matter how much money is poured into expressways, freeways and throughways, no permanent solution of the urban transportation problem will be reached until mass transportation is accorded operating rights comparable to those being provided the automobile. It is for the convenience of the majority of persons, rather than the majority

of vehicles, that traffic regulations should be adopted and enforced."

Mr. Simpson, in advocating separate lanes and separate streets for transit vehicles, also said: "The situation of the mass transit vehicle will tend to deteriorate further unless we reverse the trend toward moving more and more automobiles faster, and implement plans to permit transit to carry more people faster in less street space."

Committees Study Traffic Problem

At its twenty-fifth annual meeting in Pittsburgh in October, 1955, the Institute of Traffic Engineers conducted a work conference on "An Evaluation of the Traffic Problem and Its Future." A major finding was that by 1975 street and highway traffic in the United States will double in volume. The special work conference of forty engineers estimated there will be 120,000,000 motor vehicles twenty years hence. In metropolitan areas, the engineers foresaw the central business district as remaining the hub of urban life and the biggest single generator of traffic.

But, they cautioned, the future of downtown will depend upon improved transportation to the area, and this will necessitate improvements in mass transit as well as in parking and in highway access. Mass transit, the engineers said, will continue to play an essential role, but will be able to perform its important function only if outmoded restrictive regulations are removed and if transit receives more favorable consideration in the use of city streets and in the design of new traffic facilities.

In an unprecedented cooperative effort, six national organizations of municipal officials have banded together to sponsor and carry out a project to develop procedures for a fact-gathering program on which to base future plans for the movement of persons and goods in urban areas. This National Committee on Urban Transportation—a cooperative organization with which the transit industry through the American Transit Association is cooperating fully—is seeking the optimum combination of street facilities, off-street parking facilities, and urban transit services, so the public transportation dollar may be spent most efficiently.

Comprising the National Committee are: American Municipal

Association, American Public Works Association, American Society of Planning Officials, International City Managers' Association, Municipal Finance Officers Association, and National Institute of Municipal Law Officers.

Transit's role in alleviating traffic congestion received extensive consideration at the annual American Municipal Congress in Miami. The general theme of transit and traffic experts participating in a special panel discussion was that transit riders, as citizens and taxpayers, are entitled to the same consideration in transportation facility construction and operation as that accorded to owners of private automobiles. The panelists agreed that transit's problem is to win back some of its lost riders, that this can be done only by providing faster transit service, and that to provide faster service transit systems must have the cooperation of municipal officials.

Even in the forthcoming national presidential race this subject has received attention. Speaking at one of the general sessions of the American Municipal Congress, presidential aspirant Adlai E. Stevenson put in a word for better transit as a means of alleviating traffic congestion. Listing recommendations for curing municipal headaches, Mr. Stevenson called for "a two-level attack on traffic congestion to improve our mass transit systems, and to break the bottlenecks and permit traffic to move freely around and through our cities."

The increased number and use of private cars, he stated, "is creating more problems than it solves in obsolescent city streets that flow between narrow banks of ever-taller buildings that cannot be pushed back. As we struggle to impose an automobile civilization on an elevated civilization, we note painfully that the farther and faster we grow in a vertical direction, the slower we move horizontally."

Municipal Officials Seek Solution

At the same meeting, prominent municipal officials sponsored a resolution recognizing the transit situation and urging complete cooperation of all levels of government.

In draft form, the resolution called upon the federal government to provide for public transit rights-of-way in federally-supported urban highway or expressway projects and to provide for construc-

tion of park-and-ride lots at key interchanges. It also recommended exemption from federal gasoline and other excise taxes.

State and municipal governments were asked to exempt transit from franchise and other special taxes, and municipalities were advised to finance construction of transit facilities for lease to private operators; also, to consider reserving streets or lanes for exclusive transit use and making available public property for park-and-ride lots on the fringes of the city.

While this resolution was not adopted as introduced, its consideration indicates the growing concern over what is being recognized as a single problem—the problem of transit and traffic congestion. In many cities, municipal officials are taking cognizance of the rather simple arithmetic which shows how greater use of transit will break up downtown traffic jams. Traffic engineers find that on the average automobiles downtown carry one and one-half persons. Thus, for every three people who can be wooed back to transit, two cars can be kept off crowded downtown streets.

To persuade people to make the switch, transit has been endeavoring to improve its service, to offer a better, more dependable and faster ride. The faster ride is the number one requisite, and to offer it transit must have—and in some cases receives—community cooperation. Municipalities show increasing inclination to adopt specific suggestions for giving transit a better opportunity to play its full role in moving people.

Some of these steps are: providing separate streets, or at least separate exclusive lanes for the transit vehicle; routing transit vehicles more directly to cut travel time and bring riders closer to important destinations; allowing for transit lanes in expressway construction; reducing peak traffic loads by staggering work hours; developing fringe parking lots to ease traffic; restricting on-street parking, stopping, loading, and delivery where they interfere with transit, not only downtown, but during rush hours for considerable distances along principal arterial streets; prohibiting turns, right as well as left, at important downtown intersections; timing traffic signals in line with transit requirements, rather than those of private cars, and promulgating parking charge combinations to favor the short-term, rather than the all-day parker. Enforcement, of course, is the key to successful application of these devices.

Easing—and in some cases, elimination—of antiquated taxes peculiar to the transit industry have helped transit systems weather the financial distress of the last several years in which the industry has been caught in a squeeze between rising costs and declining patronage. A few of the cities which have eased the tax burden of their privately-owned transit systems, are: New York, Miami, Pittsburgh; Oakland and San Jose, California; Denver, Dallas, Houston, Washington, D. C.; Springfield, Illinois, Des Moines, Wichita, Kansas City, Omaha, Albuquerque, and many others.

States Grant Transit Tax Relief

In the last five years, ten states acted to grant tax relief to transit systems. In California and Virginia, franchise taxes were reduced. Kentucky and Massachusetts have cut seat taxes. Ohio and Pennsylvania reduced gross receipts taxes. Michigan reduced its fuel tax as paid by transit operators. Texas also reduced transit fuel taxes and license fees as well. In Tennessee, registration and inspection fees were reduced.

The 1955 Wisconsin legislature adopted a law exempting transit firms from state motor fuel taxes and municipal license fees and fixed the charge for annual license fees at one dollar per vehicle. The same law makes a new tax applicable only to transit companies, requiring them to pay the state 50 percent of all net profits, after federal income and excise taxes and after deduction of an eight percent return on the depreciated cost of their operating property. Of the new tax, the state retains 15 percent, the counties receive 20 percent and the municipalities 65 percent.

Even at the federal level, there has been action to assist the transit passenger in so far as taxation is concerned. Last summer, when the multi-billion-dollar highway program was before the Congress, there was written into the legislation for financing the work an exemption for most of the transit industry from proposed new and steep taxes on fuels and tires.

While these actions undeniably assist transit systems, the relief thus afforded is only of short-term value. Much more beneficial are the traffic measures initiated to give transit greater freedom of movement.

Similarly, greater freedom to experiment with fares and service would be extremely valuable to the industry. The industry was considerably heartened by a recent panel discussion during the annual meeting sessions of the National Association of Railroad and Utilities Commissioners. Four panel members and a moderator—all men who regulate the transit industry—expressed confidence that transit would be given the regulatory, tax, and traffic assistance it needs to stage the comeback so necessary to America's cities in their efforts to revitalize themselves and to insure their growth and development as the hubs of expanding metropolitan areas.

Promise of Effective Results

Such progressive and long-range thinking by the regulators of the industry hold much promise for a brighter future for transit and its customers. Given the greater freedom which even the regulators of the industry say it should have, transit is confident it can do the better job it needs to do.

Another contribution toward alerting the general public to the essentiality of transit and to the need for making greater use of public transportation downtown was made recently by General Motors Corporation. The transit industry attaches much significance to the fact that the world's largest manufacturer of automobiles produced and distributed for free showings a sound motion picture film in color devoted to this subject. Called "Let's Go To Town," the film urges commuters and shoppers to leave their cars at home when heading for downtown, and suggests preferential treatment such as reserved lanes and streets for motor buses which make economical use of scarce street space.

Encouraged by these and other developments, and hopeful that the trend will continue toward identifying the transit problem with the traffic congestion problem and transit's interests with the public interest, the transit industry is making long-range plans. A new national committee is taking bold steps to develop the bus of tomorrow, which will have more eye appeal, will take into account customer-desires to a greater extent than ever before, will add dignity to riding a transit vehicle, and will provide maximum rider comfort and convenience.

Transit still has a long way to go to emerge completely from the isolation ward of city planning. The important thing, however, is that it is emerging, that policies which all but omitted public transportation from plans for the daily movement of vast numbers in congested areas now are beginning to be recognized as fallacious. Reversing the trend which has catered largely to the automobile is not going to be easy. For in seeking the Utopia of individualized transportation our cities have created some roadblocks of fixed opinion difficult to dissolve. Expenditures to accommodate the automobile driver have produced the widely held belief that a solution of the problem could be achieved in this way.

It will require a high degree of political and civic courage to reverse the trend; to admit past planning errors; to recognize that higher and higher expenditures for street widening and parking facilities may serve only to lure more and more cars—but fewer people—downtown.

Forecasting Zonal Traffic Volumes

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THE principal purpose of a traffic study should be to develop a master plan of transportation facilities that will serve the area being studied for years to come. Any good improvement program requires time to plan and construct and has a long and useful life. Benefits will accrue for future users. It is imperative, therefore, that the planning consider future traffic volumes.

Future volumes should be considered from two points of view: first, estimates of change in volumes, and second, estimates of change in the geographic distribution of traffic throughout the area. The derivation of either of these estimates requires the collection of data during some base period so an estimating procedure can be developed.

The Detroit Metropolitan Area Traffic Study conducted an origin-destination survey in the fall of 1953. Data collected in this survey provide an inventory of traffic occurring in the area at that time. The data also provide a basis for the comparison of the inventoried traffic volumes with other variables so that a method can be developed for predicting future traffic volumes based on the forecast of the associated variables. For example, the total trips made to or from any zone within an area are associated with population, nature and intensity of land use, car ownership and other factors. Thus, if the future population, land use, etc. can be predicted, the future traffic generation can be predicted.

Further problems of forecasting volumes of zonal interchange can be similarly solved. The distribution of these volumes for any zone of origin is associated with the relative attractiveness of all possible zones of destination as modified by the relative amount of friction incurred in traveling between the zones. The relative at-

tractiveness of the zones of destination can be measured by the number of trips generated by the various zones. The relative travel friction may be estimated by using distance traveled, time in transit, or possibly other variables. It then follows that if zonal trip volumes can be forecast and the travel frictions measured, zonal interchange volumes can also be forecast.

Given interchange volumes as measured by an O-D survey and estimates of the future number of trips generated by different zones within an area, it is possible to develop a method for predicting the future distribution of traffic throughout an area.

Review of Previous Methods

We have various methods for predicting the distribution of traffic throughout a metropolitan area. The most elementary form of prediction expands all zonal interchange volumes obtained in an O-D survey by the expected amount of growth for the entire area. This method assumes that traffic volumes in all parts of the area are equally affected by growth in the area as a whole. This overemphasizes trip volume where land is already intensively developed and underestimates volume in areas having high rates of growth in population and land use. Differential rates of land use development will produce differential rates of growth in traffic volumes.

One of the first methods attempting to correct for differential rates of land development was that of "Averaging Growth Factors."[1] In this method, a traffic growth factor for each zone within an area is computed. This growth factor is the ratio of the traffic resulting from the anticipated land use development at a future point in time to the traffic generated by the land in its current state of development. The future interchange between any two zones is postulated as being equal to interchange in the base period multiplied by the average of the growth factors for the terminal zones. This method produces an error similar to that of the flat rate extrapolation described above, only on a smaller scale. In other words, the sum of the future interchange volumes involving any given zone usually would not equal the postulated number of trips generated by that zone.

[1] St. Paul-Minneapolis O-D Survey, letter report to H. S. Fairbank from Ira E. Taylor for the Division Engineer, November 10, 1954.

Thomas J. Fratar[2] realized this problem and advanced a procedure using iterations or successive approximations until an answer was obtained that produced an interchange pattern and yet balanced with the postulated future zonal volumes. He states that the future interchange between two zones is determined by the size of the zones in terms of trips terminating there and the relative attractiveness of the various interchange possibilities. Relative attractiveness is determined by interchange volumes reported at the time of an O-D survey. It is assumed that the future relative attractiveness of zones of destination for a given zone of origin is determined by the present interchange volume multiplied by the growth factor for the zone of destination. Then it is argued that the percent of zone A's trips to zone B is equal to the attractiveness of zone B divided by the total attractiveness of all of the zones of destination. Thus Fratar's system distributes the trips of zone B to all other zones, and so on.

Under this system, the estimated number of trips between A and B when distributing zone A's trips will usually differ from that when distributing zone B's trips. Hence, an average of these two estimates is taken as a first approximation of the future zonal interchange. If the total of the interchanges involving a given zone do not balance with the postulated future volume for that zone, the process is repeated using a modified growth factor until the totals converge to the desired degree of accuracy.

Fratar made a valuable contribution in demonstrating that an iterative procedure is required to provide a reasonable solution, i.e. that the forecast interchange pattern balances with the postulated future zonal volumes.

Experimentation showed that any of several different methods, when calculated on an iterative or successive approximation basis, would yield an interchange pattern that balanced with postulated future zonal volumes. This includes the method of averaging growth factors if the growth factor is modified for each succeeding iteration. The question remained as to what procedure would be most appropriate for use in the Detroit study.

[2] Fratar, Thomas J., "Vehicular Trip Distribution by Successive Approximations," *Traffic Quarterly*, January, 1954. Also see, "Forecasting the Distribution of Interzonal Vehicular Trips by Successive Approximations," paper presented at the annual meeting of the Highway Research Board, January, 1954.

It was believed that certain criteria could be established for a model used to predict zonal interchange volumes. These criteria form the limits within which a method can be developed and used whereby interchange volumes are predicted from the factors affecting these volumes. These are:

1. All trips within the system should be duly considered because certain factors cause people to substitute certain types of trips for other types. This substitution may be intra-zonal for inter-zonal trips, short for long trips, motorcar driver for transit passenger trips, or any of many other possible substitutions;

2. The sum of the future interchange volumes terminating at any zone must equal the postulated number of trips generated by that zone;

3. Results must be internally consistent. That is, the predicted trip volumes should be independent of the grouping or partitioning of zones into different size units except as this affects the number of trip termini for the zones in question.

With these criteria in mind, the method developed for predicting interchange volumes in the Detroit area will now be discussed.

The Detroit Method

The procedure in Detroit starts by defining three basic measurements for each zonal interchange. These are the actual interchange, the probability interchange, and the index of friction encountered by trips making the interchange. All of these measures can be most easily depicted in matrix form with i-rows and j-columns. There is a row and a column for each zone, so the i-rows equal the j-columns equal the zones in the area. Then, any particular cell depicted by the i'th row and j'th column will contain a measurement applicable to the interchange between a given i-zone and a given j-zone as in the following diagram.

ZONE	a	b	..	j	..	m	Total
1	Y_{1a}	Y_{1b}	..	Y_{1j}	..	Y_{1m}	$\Sigma_1 Y_{1j}$
2	Y_{2a}	Y_{2b}	..	Y_{2j}	..	Y_{2m}	$\Sigma_2 Y_{1j}$
..	..	..	..	..	..	..	..
i	Y_{ia}	Y_{ib}	..	Y_{ij}	..	Y_{im}	$\Sigma_i Y_{1j}$
..	..	..	..	..	..	..	..
n	Y_{na}	Y_{nb}	..	Y_{nj}	..	Y_{nm}	$\Sigma_n Y_{1j}$
TOTAL	$\Sigma_a Y_{1j}$	$\Sigma_b Y_{1j}$	..	$\Sigma_j Y_{1j}$	..	$\Sigma_m Y_{1j}$	$\Sigma_{i=1}^{n} Y_{1j}$*

* $\Sigma_{i=1}^{n} Y_{1j}$ equals $\Sigma_{j=a}^{m} Y_{1j}$ so that for conformance to standard notation $\Sigma_{i=1}^{n} Y_{1j}$ is used during the remainder of this paper.

Within this framework, each of the three measurements will be discussed in detail.

Actual interchange (Y_{ij}) is the volume of trips reported as of the time of the survey. For this purpose, non-directional movements were used. Then, any cell Y_{ij} shows the volume of trips between a defined zone i and a defined zone j. It must be pointed out that since non-directional trips are being used, the number of intra-zonal trips for any given zone must be doubled (or reported twice) to keep these volumes in their proper proportion with all other volumes. This becomes quite apparent when one considers that any inter-zonal movement is shown twice, e.g. as both Y_{ij} and again as Y_{ji}. Care must be exercised after future volumes have been predicted to halve the intra-zonal volumes.

The validity of using non-directional interchange volumes has been shown by tests of data from both the Detroit and the St. Paul surveys showing that the differences between the directional volumes can for all practical purposes be attributed to sampling error. In fact, it was found that for less than 11 percent of the interchanges would the difference in the directional volumes be greater than one standard error of the estimate; and for only 0.5 percent of the interchanges would the difference be greater than two standard errors. In short, the trips going will always tend to equal those coming between any pair of zones.

A matrix similar to the one above can be developed depicting the probability interchange between any zone i and any zone j

assuming that the sole factor affecting trip volumes is the relative attractiveness of the various zones in the system. This assumes that the deterrents to trip making such as distance, time and cost are equal for all possible interchanges. Then the trips generated by any particular zone are distributed among all of the zones in the system according to the percent of the total number of trip ends generated by the various zones. For example if zone i generates 100 trips, zone j generates 200 trips, and there are 10,000 trip ends in the system then zone j will draw 200/10,000 or 2 percent of zone i's trips. In this example, 2 percent of 100 equals two trips. This probability interchange (X_{ij}) can therefore be defined by the following equation:

$$X_{ij} = \Sigma_i Y_{ij} \cdot \Sigma_j Y_{ij} / \Sigma_{i=1}^{n} Y_{ij} \qquad (1)$$

The reader will note that this formulation of the probability interchange is identical to that for computing the expected frequencies used in the chi-square statistical test. By the same token that expected frequencies can be computed when a third variable is introduced into the chi-square test, probability interchange volumes can be computed when a third variable, such as mode of travel, is considered. The formulation, considering a "k" mode of travel, then becomes:

$$X_{ijk} = X_{ij} \ (\Sigma_k Y_{ijk} / \Sigma_{i=1}^{n} Y_{ijk}) \qquad (1a)$$

where Y_{ijk} is, of course, the actual interchange volume by a given "k" mode of travel.

In examining tables where interchange volumes are inserted, individual volumes shown in the two matrices are different. This is logical because the volumes shown in the matrix depicting the probability interchange volumes do not account for differences in trip-length or-trip time while the volumes shown in the matrix of actual interchanges are certainly influenced by these factors. This is true even though the total trips generated by any zone and hence the total trips within the system are the same for each matrix.

It can be postulated that the difference between the actual interchange and the probability interchange is a measure of an index of the relative friction (F_{ij}) incurred in making that particular movement. It is therefore possible to set up a third matrix where any cell

F_{ij} is a measure of the friction encountered in making trips between a given zone i and a given zone j.

Since the probability interchange volumes themselves vary greatly in size depending on the number of trips generated by the zones involved, the relationship between the actual and probability interchange volumes should be expressed in the form of an index number or ratio rather than as an algebraic difference. This argument holds even if all zones were defined at the time of the O-D survey to have an equal number of trip termini in them because differential growth throughout the area will not preserve this equality for the future point in time for which predictions will be made.

Thus, the reason for using an index number is that it presents the relationship in relative terms, e.g. the number of trips made per unit of probability interchange, and therefore accounts for differential zone size. This formulation is expressed in the following equation:

$$Y_{ij} = X_{ij} \cdot F_{ij} \qquad (2)$$

or

$$Y_{ij} / X_{ij} = F_{ij} \qquad (2a)$$

Since this relationship will hold for any point in time the problem of predicting interchanges can be defined as follows. First, the relationship as of the time of an O-D survey must be determined. Second, values for the probability interchanges and the indices of friction must be developed for the future. Finally, the operation of equation (2) is performed to predict the actual interchange volumes for the future.

Prediction of probability interchanges can be redefined as being a problem of predicting the total trips generated by any particular zone. With these totals so determined,[3] any given probability interchange can be determined by equation (1).

The problem of predicting indices of friction is quite a different matter. The best method is to obtain some measure of these indices as expressed by distance, time, cost, etc., and develop measures for the future based on these expressions of friction. Another method is to

[3] For details on a procedure used in forecasting these totals, see: Hamburg, John R., "Land Use and Traffic Generation in the Detroit Metropolitan Area," Detroit Metropolitan Area Traffic Study, mimeo., September, 1955.

assume that friction is relatively the same in the future as it is now. This does not imply that transportation facilities are the same in the future as now, but that the normal improvements made in the system provide each movement with the same relative quality of service in relation to service between other zones as is now existent.

The latter assumption of similar relative friction factors in the future is implicit in either the method of averaging growth factors or in Fratar's system of successive approximations. This is true because in both systems the interchange reported at the time of an O-D survey is used as the basis for predicting future volumes. This interchange volume is determined by the amount of friction incurred in making it in relation to the probability interchange. Consequently, if the friction were altered, the interchange volume would change and the prediction of the future interchange volume would also change. This assumption of similar relative friction indices is also made for this paper and is the basis for the discussion of calculating procedures described below.

Using equations developed above, it is possible to discuss the mechanics of the procedure for predicting future interchange volumes for the Detroit area. As in Fratar's system, a series of successive approximations is required to bring the system into balance.

Calculating Procedures

Assuming equal indices of friction in the future as exist now, an approximation of the future interchange may be developed by a modification of equation (2) as follows:

$$Y_{ij} / X_{ij} = F_{ij} = Y'_{ij} / X'_{ij} \qquad (3)$$

where:

Y_{ij} and X_{ij} refer to volumes as of the time of the O-D survey and Y'_{ij} and X'_{ij} refer to volumes at a future date.

From equation (3) it follows that:

$$Y'_{ij} / Y_{ij} = X'_{ij} / X_{ij} \qquad (3a)$$

Substituting from equation (1):

$$Y'_{ij} / Y_{ij} = \frac{\Sigma_i Y'_{ij} \cdot \Sigma_j Y'_{ij} / \Sigma_{i=1}^{n} Y'_{ij}}{\Sigma_i Y_{ij} \cdot \Sigma_j Y_{ij} / \Sigma_{i=1}^{n} Y_{ij}} \qquad (3b)$$

or,

$$Y'_{ij} = Y_{ij} \ (G_i \cdot G_j / K) \qquad (4)$$

where:

G_i is the growth factor for zone i which equals $(\Sigma_i Y'_{ij} / \Sigma_i Y_{ij})$;
G_j is the growth factor for zone j which equals $(\Sigma_j Y'_{ij} / \Sigma_j Y_{ij})$;
K is the growth factor for the area that equals $(\Sigma_{i=1}^{n} Y'_{ij} / \Sigma_{i=1}^{n} Y_{ij})$.

When estimating the future intra-zonal movement, i equals j in all equations so that these predictions can be restated as:

$$Y'_{ii} = Y_{ii} \ (G_i^2 / K) \qquad (4a)$$

If it is desired to forecast zonal interchange volumes by mode of travel then equations (3) through (4a) must be modified according to the revised definition of the probability interchange (X_{ijk}). It is left to the reader to go through the substitutions in equations (3) through (3b). The result is a modification of equation (4) as follows:

$$Y'_{ijk} = Y_{ijk} \ (G_i \cdot G_j \cdot G_k / K^2) \qquad (4b)$$

Similar changes are of course made in equation (4a).

If the theory previously developed considered all variables pertinent to predicting zonal interchange volumes, Y_{ij} would represent a final unique solution satisfying the criteria imposed upon the model. However, these criteria are not satisfied. One of the reasons for this is that the above model does not consider the changing distribution of probability interchange volumes with respect to travel frictions through time. For example, the relative attractiveness of zones of destination at varying trip lengths, as measured by the postulated future number of trips terminating in these zones, changes as population, car ownership, and land use development change. Hence, after one calculation, Y'_{ij} will be an approximate rather than a final solu-

tion and further smoothing calculations are required to yield a solution satisfying the criteria.

The procedure described in equation (4) can be iterated until the desired degree of accuracy is achieved by substituting Y'_{ij} for Y_{ij} in all calculations. Then:

$$Y''_{ij} = Y'_{ij} (G'_i \cdot G'_j / K') \qquad (5)$$

where G'_i, G'_j, and K' represent the new growth factors derived from the results of the first approximation. A final unique solution in predicting future volumes is obtained when at any iteration:

$$G_i = G_j = K = 1 \qquad (6)$$

When the growth factors for all of the zones and consequently for the system are equal to one, the sum of the trips terminating in any particular zone are equal to the postulated number of trips generated by that zone.

External Trips

A special application of this procedure must be used in predicting external trips. These trips are interrupted in transit so the problem arises of predicting station-to-zone volumes rather than zone-to-zone. It then becomes necessary to predict growth factors for individual stations or groups of stations. This is quite difficult because of possible terminal zones beyond the cordon line.

Either satisfactory growth factors for these zones must be developed or some substitute must be found for these factors. The first alternative is ruled out because of the prohibitive amount of work involved and because there is no measure of the substitutability of trips occurring wholly outside of the area for those that enter or leave it. An alternate solution must then be found.

A method of attacking this problem is to determine the expected gross volume of external trips as follows. The entire North American continent can be divided into two zones, one being the survey area as defined by the cordon line, and the other being the remainder. We can then call G_i the growth factor for the survey area, G_j the growth factor for the remainder of North America and K the growth factor for the combined areas. Because of the pure magnitude of trips to be considered, it can be argued that G_j approximates K for all practical

purposes. Then, from equation (4), the total external trips can be predicted as follows:

$$Y'_{ij} = Y_{ij} \cdot G_i \qquad (7)$$

This requires modification because a prediction of the gross number of external trips says nothing about their spatial distribution throughout the area. The modification used to get a picture of this distribution required two steps. First, the external stations were grouped into sectors. The reason for the grouping is that it is virtually impossible to assign future volumes to individual stations because the development of new roads or improvement of old ones may change the routing of the external trips.

Second, the external trips for each sector were classified according to the internal zone of trip termination. The growth factor for the appropriate zone is the one used in equation (7) to forecast the future station-to-zone interchange volumes. The total trips forecast for any external sector "j" can be obtained by the following equation:

$$\Sigma_j Y_{ij} = \Sigma_{i=1}^{n} G_i \cdot Y_{ij} \qquad (8)$$

External through trips were factored separately according to an external mean growth factor based on national and Michigan population estimates plus a car ownership correction factor.

Experience

Time to complete the iteration process depends upon three things:

1. The degree of accuracy desired;

2. The rate of closure upon the desired degree of accuracy, and therefore the number of iterations required;

3. Calculations for each iteration as measured by the number of interchange volumes to be predicted.

The Detroit Study staff decided the degree of accuracy required was an average difference of less than 1 percent for all zonal volumes as of the last iteration. Actually, the average error turned out to be only .6 percent and only 6 percent of the zones had zonal totals in excess of 1 percent different from the postulated totals.

The rate of closure or convergence toward individual zonal growth factors of 1.00 is in large part determined by the range of the original growth factors. In the Detroit area, the growth factors for individual zones ranged from about .90 to over 9.00 with an average of 1.65. Because of this wide range, the number of iterations required to balance the system is greater than if the range was, for example, from 1.00 to 3.00. It is quite apparent that if all the growth factors were equal to some constant only one multiplication is needed in forecasting future zonal interchange volumes. Therefore, the greater the divergence of the zonal factors from their average, the more iterations are required to obtain a satisfactory solution.

As the system approached a final solution through successive iterations, the growth factors tended to oscillate about 1.00 as they approached that figure. For example, a zone with an initially high growth factor would have a growth factor below 1.00 after the second iteration, above 1.00 on the third and so on. The converse is true for those zones with a low growth factor initially. Yet, this phenomenon is to be expected because of the high rates of interchange between adjacent zones which also tend to have similar growth factors. For example, if a zone has a growth factor higher than the area average, the majority of its trips will be distributed to zones also having growth factors higher than average.

Immediate closure of this model implicitly assumes that the destinations of trips from any zone are to zones that have a cross-section of the zonal growth factors of the area. Since this is not the case in the above example, the growth factors being higher than the area average, the interchange volumes for the zone will also be higher than would be expected if the system were in balance. Hence, after the first iteration, the zonal trip totals will be overstated and the modified growth factor resulting from this iteration will drop below 1.00. On the second iteration, this process is reversed. The oscillation then continues with decreasing amplitude as the growth factors approach unity.

Because of the wide range of initial growth factors and the resultant oscillation, the rate of closure was slowed down considerably. After three iterations, the growth factors ranged from about .60 to 1.30. It is apparent that this is much less than the initial range from .90 to over 9.00. On the other hand, the rate of closure was not as

rapid as expected nor as was required to maximize the use of the volumes forecast for other study purposes.

Experimentation had shown that other methods of iteration, though not as sound theoretically, would be close to an answer similar to that obtained by the system presented above. If the method of averaging growth factors is placed into an iterative process rather than being used for a single calculation, the zonal growth factors will approach 1.00 and zonal interchange volumes tend to approach similar values.

Even though it may produce somewhat different zonal interchange volumes from the method described in this paper, the amount of difference is dependent on the range of growth factors, i.e. if the range is small the differences are small. With this in mind, it was decided by the study staff that further iterations using the method of averaging growth factors would save time and yet provide no serious distortion to the data. Using this procedure, the oscillation of growth factors described above was severely dampened and it was found that after two more iterations, the range of growth factors had decreased from about .60 to 1.30 to a range of about .97 to 1.03. As previously stated, the average difference from 1.00 was .6 and only 6 percent of the zones fell outside the .99 to 1.01 range.

In retrospect, there is another method consistent with the theory expounded in this paper that could have been used to dampen the oscillations and thus increase the rate of closure. This is to use a lagged moving average of the individual interchange volumes. It has been shown above that the oscillation of the growth factors results from an oscillation of the zonal interchange volumes.

Then, the approach of the interchange volumes to their future value can be described as an oscillation around a trend. Experimentation has shown that a two-item moving average of the volume obtained on an iteration with the volume obtained on the previous iteration will severely dampen the oscillation but will not affect the trend except to hasten closure. Thus, the same results will be obtained at a great saving in time. To compute this average, equation (5) would be modified as follows to estimate Y''_{ij}:

$$Y''_{ij} = \frac{Y'_{ij}\,(G'_i \cdot G'_j \,/\, K') + Y'_{ij}}{2} \qquad (9)$$

The last item determining the amount of time required to complete the iteration process is the number of calculations required for each iteration. This in turn is a function of the number of interchange volumes to be predicted. The 254 zones and ten external station groups for the Detroit area provided a possible total of almost 35,000 different pairs of zones between which interchange can occur. Of this total only about 63 percent or 22,000 had interchange volumes reported in the O-D survey. It is for these 22,000 that future zonal volumes were predicted.

Using modern machine methods, it required twenty hours to process this volume of interchanges for each iteration. The five iterations thus required a total of 100 hours to obtain the desired degree of accuracy. If a method to dampen the oscillations had been used earlier in the process, at least one less iteration would have been needed. To the extent that a lagged moving average of the interchange volumes will yield the same final result as when no moving average is used, this modification of the procedure will save time and produce a pattern consistent with the theory developed.

Summary and Conclusions

Forecasting zonal interchange volumes requires knowledge of factors that govern the distribution of trips throughout an area. These factors include the relative attractiveness of the zonal interchange and the friction incurred in making the interchange relative to all other possible interchanges. The relative attractiveness of any zonal interchange may be considered as a function of the number of trips generated by the two zones. In this article, the attractiveness is defined in the concept of the probability interchange, this being the interchange volume to be expected if the friction were equal for all interchanges. The amount of friction incurred for a particular interchange is then measured by the relationship between the actual interchange volume and the probability interchange volume.

Assuming that this measure of friction will remain relatively equal through time, it is then possible to forecast future zonal interchange volumes, knowing what the growth for the different zones within an area is, and thus knowing what the changes in relative attractiveness are for the various zonal interchanges. After dependable

estimates of this growth are obtained and the relative measures are established from an O-D survey, the method advanced in this paper can be used to forecast zonal interchange volumes.

Experience shows that use of this method may result in a slow rate of convergence to the final solution depending on the range of the zonal growth factors. Further, this rate of closure may be typified by the oscillation of the modified growth factors obtained after each iteration. The rate of closure can be hastened by dampening these oscillations.

Experimentation shows that a method for dampening these oscillations consistent with the theory of interchange determination involves the use of a lagged moving average of interchange volumes. However, it would probably be best to examine the growth factors after one or two iterations to see if such a dampening procedure is needed. The reason is that the moving average procedure will hasten the rate of closure *only if the zonal growth factors do oscillate*. To the extent that this oscillation may not occur in some cities, the use of a moving average would retard the rate of closure.

The use of the procedure described in this paper produces an interchange pattern that appears logical and consistent in light of anticipated land use development for the Detroit area. Further, this method satisfies the criteria imposed upon it. It has been shown how all types of trips are considered and how the predicted interchange pattern balances with the postulated future zonal volumes. No formal proof has been made that the results are internally consistent. However, experimentation indicates that the predicted interchange volumes do converge to one final answer regardless of how zones are grouped or partitioned.

This method, however, is no panacea. There is a basic fault in any iterative procedure regardless of the soundness of the method itself. It is highly questionable whether the assumption is sound that friction factors will remain relatively equal through time. First, changes in driving conditions in different parts of a metropolitan area do not proceed at a relatively equal rate as the area grows. Traffic volumes and hence congestion will increase faster in the suburban areas than in the central business district.

Second, major shifts in land use development, e.g. rural to industrial, would undoubtedly affect the friction factor because people

will usually travel greater distances to go to work than to go visiting or grocery shopping. Finally, friction factors developed in the above formulas from an O-D survey are distorted by sampling error and this error is magnified by the multiplication procedures of the method.

These faults are especially noticed in those interchanges with zero volumes at the time of the O-D survey because they are forecast with zero volumes regardless of the rate of growth of the zones involved. To the extent that these volumes are understated, other interchange volumes must be overstated to meet the criteria imposed on the method. Hence, distortion is introduced into the traffic pattern.

The way to overcome these problems is to make an independent forecast of zonal interchange volumes based on some measure of friction. Such an independent forecast must of course consider all possible zonal pairs and those variables causing people to make trips to specific destinations.

It would be extremely difficult, if not impossible, to develop a model as mentioned above that would predict interchange volumes perfectly. On the other hand, one can probably be developed that would predict relative volumes quite accurately and have the zonal trip totals within 10–15 percent of their postulated volume.

After this initial forecast has been made, an iterative procedure may be used to bring the system into balance. It is in this light that an iterative procedure such as developed in this paper can best be used to provide accurate forecasts of the geographic distribution of trips.

Establishing a Priority For Local Rural Road Improvements

JOHN E. BAERWALD

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AN EFFICIENT and orderly highway system is a basic element of a dynamic society, essential to the national, state, and local economy. Such a system includes a coordinated network of rural county roads providing safe, convenient, and efficient automotive transportation when integrated with state highways and city streets. However, establishing an adequately coordinated network of county highways in many cases has been handicapped by inadequate funds and by the allocation of county highway expenditures based upon subjective information rather than objective criteria which would be of most benefit to the public interest.

Officials of Allen County, Indiana recognized the need for a study to determine the degree of public interest in each county

highway and the ability of these highways to serve the demands placed upon them. To this end, the Board of Commissioners of Allen County requested the Traffic Engineering Services Unit of the Joint Highway Research Project, Purdue University, to make an engineering analysis of the rural highways under county jurisdiction. The analysis included classification of the rural county highways into three systems of decreasing importance—the county primary, the county secondary, and the local service system—and evaluation and ranking of the county primary and county secondary highway sections in a decreasing order of urgency for improvement or reconstruction.

Benefits Derived from the Study

The engineering analysis was based on rational procedures for classifying and evaluating highways according to their current and potential use and their present physical condition. It provides officials of Allen County with an administrative tool having the following benefits:

1. Relevant facts are assembled in an orderly manner to aid in establishing priorities for the construction and reconstruction of highway sections unable, according to certain prescribed standards, to serve safely and economically the demands of traffic, abutting property, and the public interest.
2. Personal judgment is minimized or eliminated in assignment of priorities.
3. An objective basis is provided for meeting community and political pressures in highway planning and construction.
4. Administrators, councilmen, and legislators are provided with an average measure of the existing county highway plant and progress of the highway program. This progress, indicated by increased or decreased highway adequacy through periodic evaluations, provides a means of measuring the sufficiency of road funds.
5. The public's investment in the highway system is protected because funds are budgeted according to the relative order of need.

The study was not intended to be a panacea for all the road problems of Allen County. Rather, it was intended as a valuable

and practical tool to be used by those who must make policy decisions concerning the development of an adequate county highway system including the appropriation and expenditure of county funds.

Criteria for Procedures

Before the various procedures for classification and evaluation of rural county roads were adopted they had to satisfy certain basic criteria of simplicity, practicality, flexibility, and economy, all in the proper balance. Involved calculations were avoided, as well as oversimplification of procedures which could only result in faulty conclusions based on inadequate data. Design standards and total mileages placed in the classification systems requiring higher type roads had to be practical: if set too high, their attainment would have been made prohibitive, but if standards and mileages were minimized, the result would have been a definite loss in efficiency and safety.

Flexibility in procedures was desirable to enable a wide application without loss of validity and reliability due to too much latitude. Because economy should ever be the highway administrator's watchword, the criteria were balanced with economy of operation. Perhaps it would be better to say that these criteria of simplicity, practicality, and flexibility were tempered with economy because the most economical procedures were often far from being the best and most reliable methods.

Allen County Largest in Area

Allen County is the largest in land area and the fourth highest in population of the Indiana counties. In the north-eastern part of the state, it has a land area of 671 square miles and a population approaching 200,000 persons. Most of these people reside in Fort Wayne, the county seat and the state's third largest city. It may be observed in Table 1 that 76.4 percent of Allen County's population was classified as urban in the 1950 census. A county population of approximately 212,000 persons is indicated for 1960 if the 1940 to 1950 trend continues.

TABLE I

Allen County Population Data—1950 Census

	Persons	*Percentage of Total*	*Percentage Increase 1940 to 1950*
Total County Population	183,722	100.0%	18.5%
Urban—Fort Wayne	133,607	72.7	12.8
Urban—Non Fort Wayne	6,707	3.7	*
Rural—Non Farm	27,873	15.2	*
Rural—Farm	15,535	8.5	*

* Not classified in 1940 census.

There were 88,498 motor vehicles registered in the county in 1954 and according to the rate of increase, the registration will reach about 107,000 vehicles by 1960. On the basis of this registration and other factors, Allen County received $726,368.19 from the state motor vehicle highway account during 1954. If the trends, rates, and methods of distribution remain the same, approximately $980,000 in motor vehicle receipts may be available to Allen County in 1960.

Further analysis of the economic status of Allen County shows a significant change in agricultural income. It has increased from an estimated $6,370,000 in 1939 to an estimated $19,379,000 in 1949 and to an estimated $22,230,000 in 1954. These data are for a period of increased agricultural production which generally requires the use of heavier and more efficient equipment on farms and highways.

Faced with the possibility of increases in population, vehicle registration and character of highway use, officials of Allen County recognized that the present funds, which represent approximately $1.32 per mile of county highway per day, must be budgeted wisely to permit immediate beginning of an improvement and modernization program. Although an increase in highway funds has been estimated for 1960, it may not exceed $1.78 per mile per day, if the total county highway mileage does not change.

The present network of 1,512.20 miles of Allen County highways represents the largest county road system in Indiana. This mileage consists of various surface types shown in Table 2.

TABLE 2

Mileage of Allen County Roads—By Surface Type

Surface Type	*Mileage (As of May 9, 1955)*
Unimproved	12.00
Gravel or Stone	1,175.34
Low Type Bituminous	240.82
High Type Bituminous	31.39
Portland Cement Concrete	45.50
Concrete and Bituminous	7.15
Total	1,512.20

The engineering analysis was concerned with the 1,224.2 miles of county highways which are rural in character, and the major roads in the fringe area of Fort Wayne that are under county jurisdiction. The remaining 288 miles are in urban or suburban areas of the county and were not included in this study.

Rural County Road Classification

Most highway engineers and administrators agree that it is not only unnecessary but undesirable to build and maintain all county highways to high-type standards. Indiana counties do not presently have sufficient funds, equipment, materials, and manpower to undertake a highway program of such magnitude, nor can they expect to have them at an early date. Consequently, it is necessary that the various highways be classified according to their relative importance. The importance of a given highway will vary among different individuals as their dependence on that highway varies, so it is essential that any classification of county highways be made in the public interest.

Before county highways can be classified into systems it is necessary to determine how many different systems are practical and necessary. Careful consideration of Indiana governmental, financial, and physical conditions led to the conclusion that three systems of county highways are most desirable.

The degree to which a highway fulfilled the primary purpose of county highways—to serve local traffic, abutting property, and the community—was used in the Allen County Study to classify the

road as a county primary highway, a county secondary highway, or a local service highway. The ultimate objective of any classification system is to provide a coordinated arrangement of state highways, county primary, county secondary, and local service highways, and city streets which will adequately fulfill the present and foreseeable future needs of the county.

Traffic volume and character of use should play a major part in classifying county highways because nearly all Indiana county highway revenues are derived from highway-user imposts. On the other hand, the effect of abutting property cannot be completely ignored because of the direct relationship between land use and traffic generation. Community interest is indicated by the service rendered by the highway. This service may be measured by study of the areas or locations linked together by the road. Service routes or special use made of the highways may also warrant consideration.

Future growth and development must also be evaluated to provide a coordinated highway plant which will provide for future as well as current requirements.

Traffic Volumes and Character

Before a county highway can be classified or evaluated, it is essential to have information available concerning the volume and character of traffic using the road. In 1937, the Highway Planning Survey Unit of the Indiana State Highway Department made a complete traffic count on every county highway. This information was placed on a traffic volume map indicating various volumes by different legends.

Changes in road use, land use, and population since 1937 have outdated much of the 1937 data. Consequently, current information concerning traffic volumes was the first requisite for developing a rural county highway program.

Through the cooperation of nearly two hundred volunteer workers, all traffic entering and leaving 125 rural intersections was counted on March 9, 1954 from 9 A.M. to 1 P.M. and from 2 P.M. to 6 P.M., because approximately fifty percent of the daily traffic uses the roads during these periods. County highway employees made classified 24-hour counts at five additional intersections for control purposes.

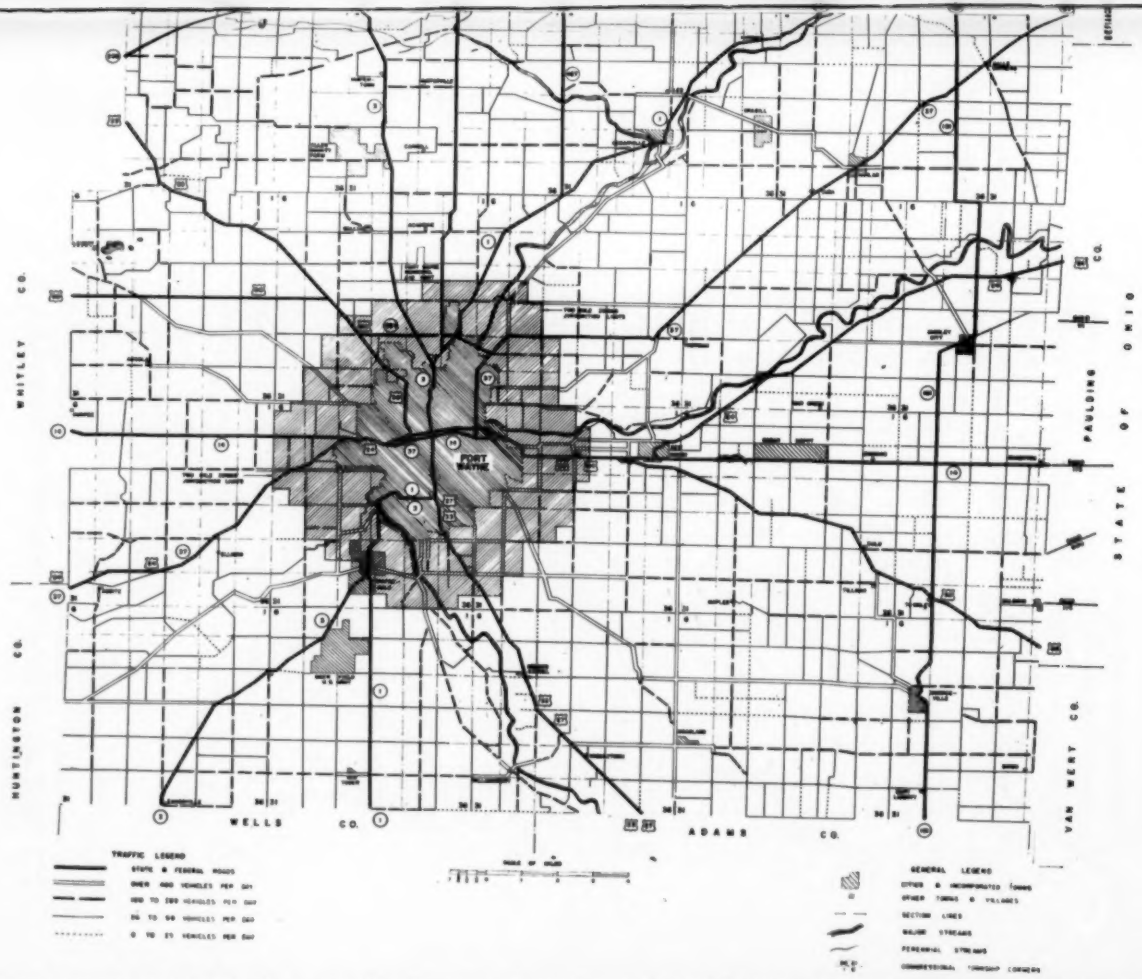

FIGURE 1. County road classification map, Allen County, Indiana. Prepared by Joint Highway Research Project, Purdue University, 1954.

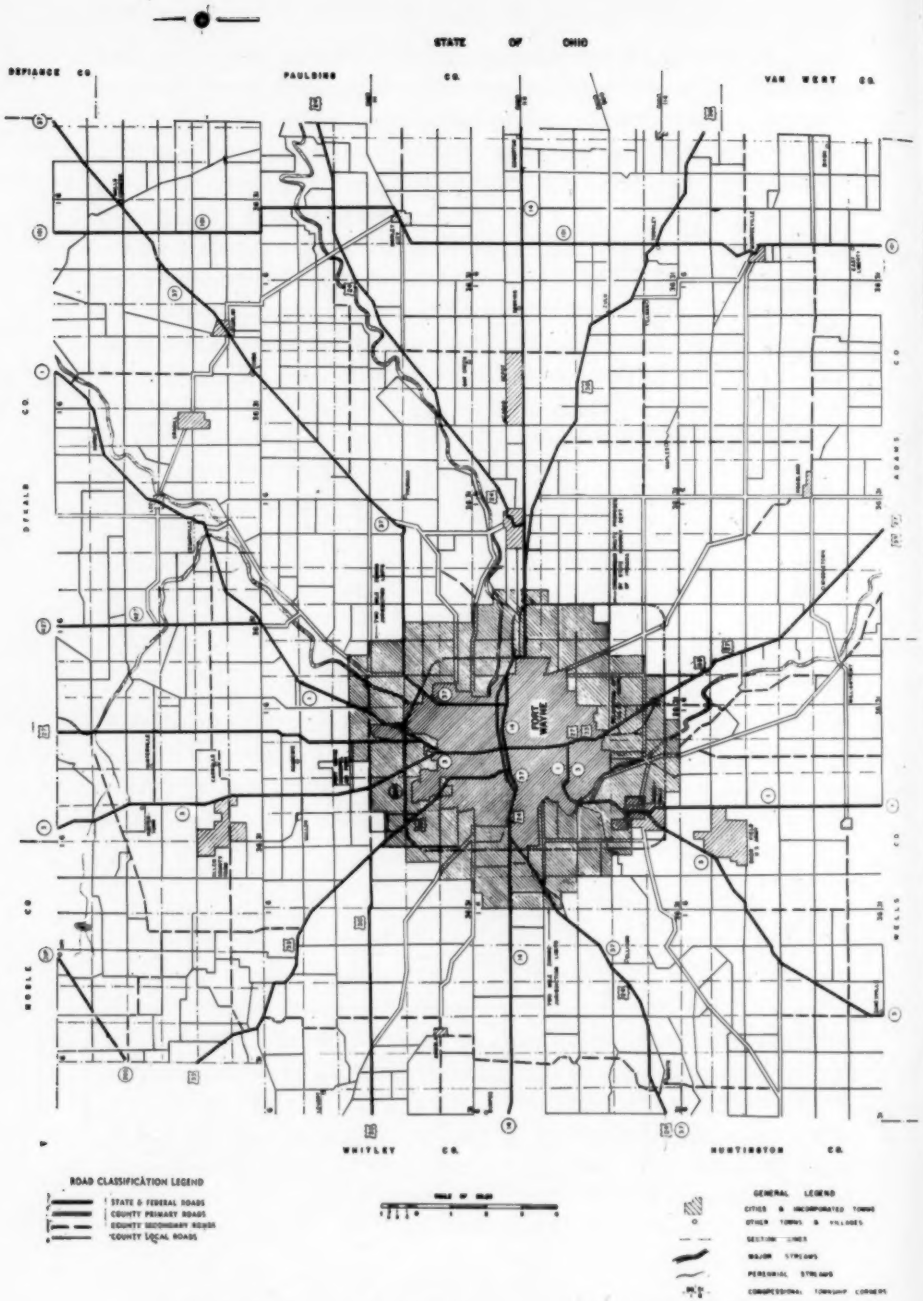

FIGURE 2. County road classification map, Allen County, Indiana.
Prepared by Joint Highway Research Project, Purdue University, 1954.

The facts obtained from these counts were supplemented by additional information from city officials for the Fort Wayne suburban area. All of these volumes were adjusted to represent average 24-hour volumes and were plotted on a county map shown in Figure 1.

Much of the increased traffic volume from 1937 to 1954 occurred on a relatively small mileage of county highways. Almost 13 percent of the rural roads in Allen County still carry fewer than 25 vehicles per day as indicated in Table 3.

TABLE 3

Rural Allen County Road Mileage Carrying Various Daily Traffic Volumes in 1937 and 1954

Average Daily Traffic Volume (Vehicles per day)	*1937 Rural Mileage*	*1937 Percentage*	*1954 Rural Mileage*	*1954 Percentage*
0–25	237.83	19.7%	156.2	12.8%
26–99	629.13	52.2	596.05	48.7
100–399	288.78	23.9	321.93	26.3
400–999	46.60	3.9	113.23	9.2
Over 1000	3.40	0.3	36.80	3.0
Total	1205.74	100.0	1224.21	100.0

Of special importance is the fact that 400 or more vehicles per day were carried by 4.2 percent and 12.2 percent of the rural county highway mileage in 1937 and 1954, respectively.

The average daily traffic volume data also provided limits for design standards. One common practice for local roads is to set reasonably high standards for average volumes in excess of 400 vehicles per day, intermediate standards for average volumes between 100 and 400 vehicles per day, and lower standards for average volumes of fewer than 100 vehicles per day. These limits, recommended for Indiana counties, were used in the study.

Data on Abutting Land Use

Proper highway classification can only be made when the abutting land usage is known, because the necessity for and travel upon any county road are directly related to the manner in which the land

adjacent to the road is used. For example, roads through highly productive farmland may have high seasonal, but low annual traffic volumes: roads through relatively poor farmland subject to suburban, residential development, may serve high volumes of traffic throughout the year. Cultural institutions are handicapped if the highways serving them are impassable much of the time and if roadside and other recreational facilities may be patronized only during favorable weather conditions. This situation causes greatly fluctuating traffic volumes on highway access roads.

Facts about the frequency and type of roadside development were obtained in the field and compared with existing records. The field study was made concurrently with the road inventory.

Determining Community Interest

The highway classification procedure also required information on community interest that may be indicated by the areas or locations connected by the highway. A road may serve as a vital connecting link between a small community and a large city or a state highway. Another road may carry volumes of traffic between two state routes or connect an important or productive area with a distribution center or access highway. This information was obtained from a study of local land use maps, population maps, and a knowledge of local conditions.

The types of service routes—such as school bus, rural mail, milk collection, or heavy trucking routes—using the highway are also indicators of community interest and their relative importance varies in each county. Their locations were obtained from local school, mail and other officials. Because nearly all of the rural highway mileage carried school bus routes, rural mail routes, and milk collection routes, these service routes were of little value in differentiating between highways for purposes of classification.

General Comments on Classification

As indicated by the legend in Figure 2, only 149.7 miles of the 1,224.21 rural highway mileage in Allen County have been designated as county primary highways. These highways were so desig-

nated because their location, method of construction, and traffic character made them logical routes to develop for the flow of high volumes of mixed traffic. They may serve to connect Fort Wayne with a rural community, or as connecting links between two state highways, or to connect highly productive areas.

The county secondary system designated in Figure 2 includes 137.8 miles of rural Allen County highways. These roads generally carry less traffic than the county primary routes but usually more than 100 vehicles a day. They may also connect less important rural communities with each other and/or with county primary or state highways.

The remaining 936.7 miles of rural roads in Allen County have been placed in the county local service system. These roads, as the name implies, serve the immediate area and usually carry low volumes of traffic of fewer than 100 vehicles a day. In general, they do not serve as many people nor as much of the county and consequently may have lower design standards.

Only a minimum number of miles of county highways have been placed in the county primary and county secondary systems. It is obvious that with limited funds, the number of routes requiring higher design standards must also be limited. The number of primary and secondary highways in the fringe areas around Fort Wayne was kept to a minimum because of the possibility that many of the roads which would have to be improved would soon be lost to the county through city expansion and annexation. The rural highway mileage in Allen County was assigned to the following classification systems:

Classification System	*Mileage*	*Percentage*
County Primary	149.7	12.2%
County Secondary	137.8	11.3
Local Service	936.7	76.5
Total Rural in Study	1,224.2	100.0

An examination of Figure 2 indicates however, that every rural location in Allen County is within two and one half miles of either a state highway, a county primary highway, or a county secondary highway.

It may also be noted that a combination of state highways, county primary highways, and county secondary highways has resulted in

two access or belt lines, one fairly near and the other farther away from Fort Wayne. Various system roads connect these belt lines with the remainder of the county.

Inventory of Primary and Secondary Highways

A valuable business practice is to conduct periodic inventories of the current status of the business. The county highway administrator, like his commercial counterpart, should have a vital interest in knowing the status of the county road system. Most citizens have definite opinions concerning what is wrong with county roads and how the faults can be corrected. Consequently, when county road administrators are forced to allocate funds on the basis of opinions rather than facts, they can usually expect varied amounts of criticism from disappointed petitioners.

Generally, records describing the existing physical condition of the county road system are inadequate and often inaccurate. It was therefore necessary that the initial inventory be as complete and precise as possible. Thus, an essential element of the engineering appraisal was a complete field inventory of every mile of the county primary and county secondary highway system. All pertinent information—such as highway number or name; right-of-way, shoulder, and roadway widths; roadside culture; type and condition of the pavement and road surface; topography; horizontal alignment; safe driving speed; and gradient—was recorded for each tenth of a mile. These completed forms provide Allen County officials with a factual record of essential highway information as well as clearly indicating the location and extent of critical conditions.

An instruction manual was prepared and discussed with a special three-man crew which had been designated by the County Highway Supervisor. This crew recorded the inventory information for all the primary and secondary highways thereby making comparisons possible between sections.

County Highway Evaluations

Records showing the use, roadside development, and physical conditions of the various county highway sections are of little value

unless there are methods available for determining how well each section can serve the various demands placed on it. These methods must provide a means for comparing existing conditions with standards established to measure the relative need for and condition of the section.

Design Standards for Allen County Highways

Allen County highways are an accumulation of many years of construction, reconstruction, and maintenance. Some roads originated as Indian trails and others were developed as the needs of a growing community increased.

Over the years the types of vehicles, the number of vehicles, and the speed, size and weight of vehicles have also changed to fulfill the needs of the road users. These changes naturally required changes in the methods of road construction and maintenance.

Modern design standards for rural highways result from research by public agencies, private industries, and universities. The observations of highway engineers have also contributed greatly to modern highway design. The most emphasis was concentrated on designs for high traffic volumes not commonly found on county highways.

Through cooperative action of many agencies and organizations, nationally accepted design standards were established for all types of rural roads. These standards have been studied and in some cases modified so that, as indicated in Table 4, they represent values which, if followed, will result in economy, usefulness, and longevity in highway improvements.

Minimum and Desirable Standards

Two sets of design standards were used in evaluating the necessity for highway improvements in Allen County. These design standards have been developed to serve two purposes. The first is to provide, through the use of minimum standards, a listing of modern highway design practices, every element of which is listed at the lowest possible value permissible under current motor transportation requirements. These minimum standards are not determined by the funds available to a job, but rather, they are intended to identify

TABLE 4

Design policies for rural county roads in Indiana.

The Joint Highway Research Project Purdue University 1954

ROAD CLASSIFICATION			LOCAL SERVICE		COUNTY SECONDARY		COUNTY PRIMARY	
HOURLY * TRAFFIC VOLUME (VEHICS./30th HIGHEST HR.)			1 – 15		16 – 62		63 – 159	
AVERAGE DAILY TRAFFIC VOLUME (VEHICLES / DAY)			1 – 99		100–399		400 – 999	
			MINIMUM	DESIRABLE	MINIMUM	DESIRABLE	MINIMUM	DESIRABLE
DESIGN SPEED (MILES / HOUR)		LEVEL	35	50	40	60	50	65
		ROLLING	30	45	35	50	45	55
		HILLY	25	35	30	40	40	45
PAVEMENT TYPE			MINIMUM 5" CRUSHED STONE OR GRAVEL	MINIMUM 6" CRUSHED STONE OR GRAVEL	MINIMUM 8" CRUSHED STONE OR GRAVEL	MINIMUM 12" CR. ST. OR GR. (STABILIZED WHERE OVER 200 VPD)	PAVEMENT ON STABILIZED BASE	PAVEMENT ON STABILIZED BASE
MINIMUM WIDTH (FEET)		RT. OF WAY	40	60	50	80	60	100
		SHOULDER	4	5	5	6	6	8
		SURFACE	16	18	18	20	22	24
MINIMUM SIGHT DISTANCE (FEET)	STOPPING	LEVEL	240	350	275	475	350	540
		ROLLING	200	315	240	350	315	415
		HILLY	165	240	200	275	275	315
	PASSING	LEVEL	700	1400	900	2100	1400	2500
		ROLLING	500	1150	700	1400	1150	1750
		HILLY	300	700	500	900	900	1150
DEGREE AND RADIUS OF SHARPEST CURVE (FEET)		LEVEL	18° 318	9° 637	14° 409	6° 955	9° 637	5° 1146
		ROLLING	25° 229	11° 521	18° 318	9° 637	11° 521	7° 819
		HILLY	36° 159	18° 318	25° 229	14° 409	14° 409	11° 521
MAXIMUM GRADIENT (PERCENT)		LEVEL	10	7	8	6	7	6
		ROLLING	10	8	10	7	8	7
		HILLY	12	10	10	8	8	8
STRUCTURES	WIDTH (FEET)		18	22	20	24	24	28
	LOADING		10 T	15 T	10 T	15 T	15 T	20 T

and isolate those sections of the various county road systems which are so far below design standards that there is no question concerning their need for improvement.

The second purpose of design standards is to provide, through the use of desirable standards, a listing of modern highway design practices which should be used for all new construction or reconstruction on the several road classifications.

Some county officials may hesitate to approve the adoption of such standards because they appear too high. They should remember, however, that much of the congestion on county roads can be attributed to similar arguments of years ago, with the end results that funds were expended on the basis of design standards the county officials thought they could afford. Consequently, the cost of providing an adequate highway is now greater. The multiple costs of delay and lack of safety which resulted each year after the insufficient standards were used must also be considered.

These design standards were developed with the help of several persons in Allen County and elsewhere in the state. Each item was carefully evaluated in respect to conditions and experience in Allen County.

Rural Highway Evaluation Elements

Study by members of the staff of the Purdue University Joint Highway Research Project showed that the most representative, realistic, and desirable approach to procedures for rural county highway evaluation should include a measure of the use or service provided by the highway section under question, which was called the Service Rating, and a measure of the physical condition of that section, which was called the Road Rating.

As stated previously, the primary purpose of county highways is to serve local traffic, abutting property, and the community. Information concerning the volume and character of traffic was available from the traffic count and knowledge of the land use of abutting property was obtained from the road inventory. Community service was indicated by the use of certain roads for rural mail routes, school bus routes, and other public services.

With the daily traffic volume carrying the most weight, it seemed

obvious that the more of these three elements that existed along a given section of highway, the more critical was the urgency for providing a satisfactory highway to serve this demand. If two road sections had identical unsatisfactory design features but one road carried a high daily traffic volume through a region of concentrated roadside development, while the other carried a relatively low traffic volume through undeveloped lands, there seemed to be no doubt that the former should have priority.

Road Ratings

The ability of a highway section to satisfy service demands was measured when the elements of structural adequacy, geometric design, and safety were compared with design standards. The most important of these was structural adequacy that included such elements as pavement type, pavement condition, roadside drainage, structures, and railroad grade crossings. If these elements are in critical condition, especially pavement condition and structures, the ability of that section of road to provide satisfactory service is definitely limited.

Geometric design elements included right-of-way, pavement and shoulder widths, gradient, and alignment. The most important of these elements was pavement width, and consequently, it was weighted higher in the rating process.

The safety category included such elements as vertical sight distance, surface condition, safe driving speed, passing opportunity, and shoulder condition.

Description of Evaluation Elements

Following is a detailed explanation of how each element was rated:

Service Rating—Maximum 50

1. Traffic—Maximum 25. The average daily traffic was obtained from the expanded traffic count data. The point value for the various traffic volumes was obtained from a straight line curve.

2. Roadside Culture—Maximum 13. Information concerning the roadside culture along the county highways was obtained during

the inventory. The points allocated for the various culture items was as follows:

a. Recreational facility—two points for each location.
b. Church—two points for each.
c. School—two points for each.
d. Business establishments—the total number of business establishments was divided by the length of the section in miles. One point was added for every three business establishments per mile and an additional point was added for any remaining fraction per mile.
e. Industrial plants—two points for each.
f. Non-farm dwellings—the total number of non-farm dwellings was divided by the length of the section in miles. One point was added for every nine non-farm dwellings per mile and an additional point was added for any remaining fraction per mile.
g. Farm dwellings—the total number of farm dwellings was divided by the length of the section in miles. One point was added for every three farm dwellings per mile and an additional point was added for any remaining fraction per mile.

Though more points could have been accumulated, no more than the maximum of 13 points was assigned to the roadside culture factor.

3. Service Routes—Maximum 12. Through the cooperation of Allen County mail, school, and dairy officials, information was obtained concerning what county highways carried the various service routes except in Eel River, Perry, and Cedar Creek Townships, where repeated requests for the location of school bus routes were ignored.

a. Rural Mail Route—five points were added if the highway section carried a rural mail route.
b. School Bus Route—five points were added if the highway section carried a school bus route.
c. Milk Collection Route—two points were added if the highway section carried a milk collection route.

Road Rating—Maximum 100

1. Structural Adequacy—Maximum 40.

a. Structures—Maximum 15. All structures less than 20 feet in length were evaluated as part of the road section. A highway section with no structures 20

feet or longer received the maximum of 15 points. The remaining structures were evaluated with major emphasis on width and load capacity.

b. Railroad Grade Crossings—Maximum 4. Highway sections which had no railroad grade crossings received the maximum of four points. Existing crossings were evaluated by deducting points for different crossing conditions.

c. Pavement Surface Type—Maximum 10. Information describing the type of surface was obtained in the inventory, and the various pavement types received point values ranging from 1 to 10.

d. Pavement Condition—Maximum 5. The inventory crews were instructed to describe the pavement condition as excellent, good, fair, or poor. A representative value for the road section was placed on the summary sheet and the point values found through the use of rating curves.

e. Roadside Drainage—Maximum 6. The condition of the roadside drainage facilities was described in the inventory as (1) excellent, (2) good etc. Points for the various conditions were obtained through the use of rating curves.

2. Geometric Design—Maximum 30.

a. Right-of-Way width—Maximum 6. The right-of-way width was measured by the inventory crew. The point value for the different widths was obtained from the appropriate rating curve.

b. Pavement Width—Maximum 8. This factor was evaluated in a manner similar to item "a" above.

c. Shoulder Width—Maximum 6. This factor was evaluated in a manner similar to "a" above. The combined width of both shoulders was tabulated on the summary sheet and evaluated with the rating curves.

d. Horizontal Alignment—Maximum 6. The inventory party recorded the frequency of curves for each tenth of a mile as none, one, few, or continuous. A representative value for each highway section was compared with the rating curves. As the topography deviated from the level, an increasing number of curves became tolerable.

e. Gradient—Maximum 4. The highest prevailing grade was recorded for each tenth of a mile as good (0–3%), fair (3–6%), or poor (over 6%). Like the horizontal alignment element, higher grades become more tolerable as the topography becomes rougher.

3. Safety—Maximum 30.

a. Surface Condition—Maximum 8. The surface condition was rated as excellent, good, fair, or poor. The points for the representative condition rating were obtained through use of the rating curves.

b. Shoulder Condition—Maximum 4. This factor was evaluated in a manner similar to item "a" above.

c. Safe Driving Speed—Maximum 5. The minimum safe speed point value

was obtained from the rating curves where the minimum safe speed as recorded in the inventory is compared with design speed for that highway and topography classification.

d. Vertical Sight Distance—Maximum 8. The vertical sight distance was recorded in the field as excellent (over 1500 feet), good (between 1000 and 1500 feet), fair (500–1000 feet), or poor (less than 500 feet). The rating curves were used to determine the point value of existing conditions.

e. Passing Opportunity—Maximum 5. The passing opportunities were described in the inventory as excellent, good, fair, or poor, and the point values were obtained from the appropriate rating curve.

A Priority Rating for Highway Improvement

The service rating factor furnished a measure of the service to be provided by a given section of highway while the road rating factor furnished a measure of the physical condition of the highway section. The critical requirement still remained to relate these two factors to each other in order to establish a numerical priority for improvement. This priority value had to be impartial and actually portray the relative needs of the various road sections.

A mathematical relationship called the priority rating was developed to enable Indiana county highway officials to rank the various highway sections, within a given classification, in a numerical order of priority. The formula for this relationship is

$$\textit{Priority Rating} = 2.5\,(\textit{Service Rating})^{1.88}\,\textit{Log}\left[\frac{100}{\textit{Road Rating}}\right]$$

This relationship between the service rating and the road rating satisfies the following desirable conditions:

1. Roads which provide a minimum of service should have a priority rating which approaches a minimum value regardless of condition.

2. Roads which are ranked near the maximum as to condition (i.e. high road rating) should have a priority rating which also approaches a minimum value regardless of the service provided by that road.

3. For a constant service rating the rate of change of the priority rating should increase as the road rating decreases.

4. For a constant road rating the rate of change of the priority rating should increase as the service rating increases.

These desirable conditions are evident in the family of curves based on the equation indicated in Figure 3. The priority rating is expressed in terms of practical values ranging from 100 to 1. High numerical values of the priority rating indicate a greater need for immediate attention on the part of county highway officials than lower numerical values.

The equation was applied to the primary and secondary highway sections in Allen County. The priority ratings of the fifty-eight primary sections ranged from ninety-one (this section had a service rating of thirty-eight and a road rating of forty-one) to seventeen (this section had a service rating of twenty-one and a road rating of seventy-one) as shown in Figure 3. The service rating values obtained for the primary sections ranged from forty-five to eighteen and the road rating values ranged from seventy-six to forty-one.

In the fifty-three secondary sections, the priority rating ranged from forty-four (derived from a service rating of thirty-eight and a road rating of sixty-five) to two (derived from a service rating of three and a road rating of sixty). The service ratings of the secondary sections ranged from thirty-eight to three and the road ratings ranged from seventy-six to forty-nine.

Use of the Priority Rating Factor

The priority rating factor was developed to rank highway sections within a given highway classification. In other words, county primary highways are not to be compared with county secondary or local service highways, or vice versa, because the road ratings are based on different design standards. County administrators should decide how funds are to be allocated between the various classification systems and then use the priority ratings to establish the urgency of various highway sections within the classification system.

The ranking of the various highway sections should be considered as the important purpose of the priority rating function. Because all rankings of highway sections are relative, it does not matter if the various field evaluations are consistently high or low so long as they are consistent.

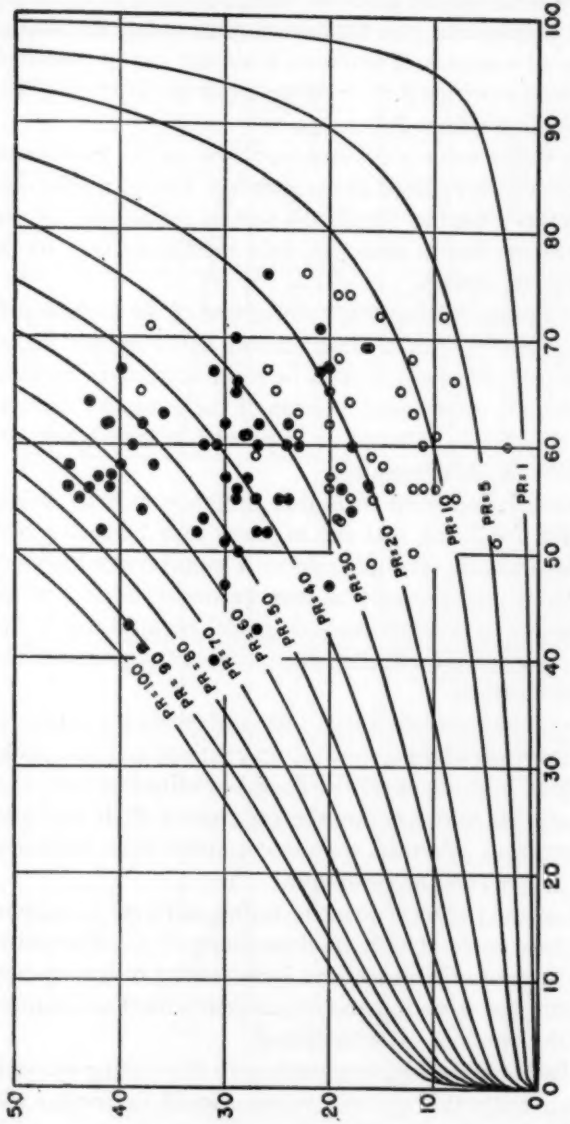

FIGURE 3. Priority Rating Curves
Based on Formula

$$\text{Priority Rating} = 2.5\ (\text{Service Rating})^{1.25}\ \text{Log}\left(\frac{100}{\text{Road Rating}}\right)$$

More experience with the priority rating function is necessary before definite conclusions can be drawn concerning the actual numerical value of a section. Therefore, it should not be assumed that a highway section with a P.R. = 80 has twice the urgency of another highway section with a P.R. = 40.

The priority rating value is dependent on the service rating and road rating values that are placed in the formula. Thus, any changes either in the methods used to obtain the service rating and/or the road rating values, or due to changing field conditions may result in a different priority rating.

Although a highway section may receive one of the highest priority ratings within a particular classification, this does not necessarily mean that it should immediately be reconstructed to include a high type pavement. After consideration of the economic factors, and if feasible, the highway should be improved to the highest design standards for that classification.

It should not be improved to higher design standards unless there is a distinct possibility that the highway may be reclassified into a higher classification. For this reason, a local service highway with a high priority rating would, at best, be improved to a minimum of eight inches of crushed stone or gravel because this is the highest, or desirable, design standard for pavement type under the local service classification.

Periodic re-evaluation of the various use and condition elements will enable officials to determine new priority ratings and new rankings of the various highway sections. Such re-evaluation will also enable county officials to determine the progress of their highway improvement program provided adequate construction, maintenance, and fiscal records also are available.

A summary of the different priority rating mileages (as shown in Figure 4) can be compared with previous summaries to determine whether the mileage of critical sections is increasing or decreasing, following concentrated attention and expenditures on these sections as indicated by the previous priority ratings.

Although a listing of the highway sections in descending numerical order of their respective priority rating should determine the priority schedule, attention should be directed toward sections with excessively low structural adequacy, geometric design, or safety fac-

tors. An analysis of local conditions should be made to determine excessively low values for these factors.

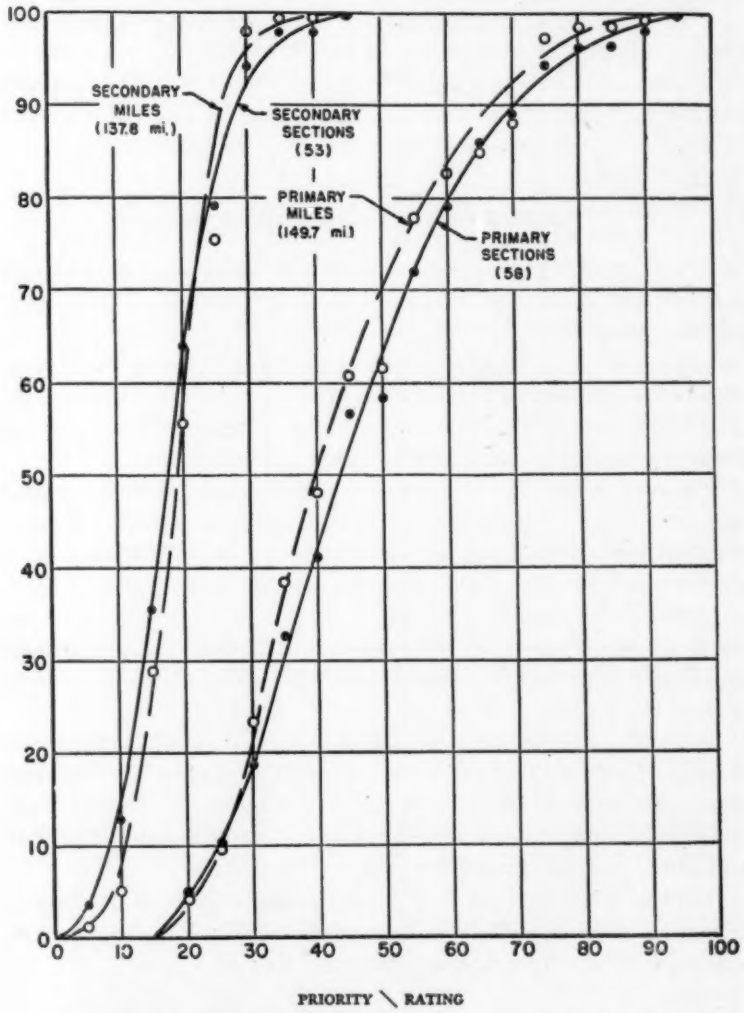

FIGURE 4. Priority rating accumulation curves for county primary and county secondary highway sections in Allen County, 1954.

It is natural that one of the first questions to arise in the minds of county highway administrators when they are discussing various highway improvement projects is, "What will it cost?" To facilitate an immediate answer, the data for the highway sections were summarized on the form shown in Figure 5. Provision was made in columns 8 and 11 for two estimates of total cost. The former column lists the estimated total cost if the highway section is to be improved to minimum design standards.

Improvement and Reconstruction Costs

Such an estimate may include the cost of improving surface and drainage conditions, pavement and shoulder widths, and structures, but may exclude the cost of changes in gradient or alignment because such changes would only be practical if the highway were completely reconstructed. The latter estimate, listed in column 11, includes the cost of completely improving or reconstructing all necessary features on the existing or on a new location.

Because the total improvement or reconstruction cost of a project may be of such magnitude as to discourage further consideration, the total cost is divided by the service rating to express the cost on a service unit basis. These unit costs are listed in columns 9 and 12.

Another means for comparing the costs of improving or reconstructing various highway sections is given in columns 10 and 13, where the average improvement or reconstruction costs per mile are tabulated.

Allen County officials were asked to evaluate these various cost estimates in the light of local conditions. It is neither desirable nor practical to improve only those sections having the lowest cost. Thus, expenditures allocated on a service cost basis may benefit the greatest number of persons per dollar spent.

On the other hand, it may be desirable to improve as large a mileage as possible with a given expenditure. If this is the case, low cost-per-mile projects must be studied with other factors.

Survey Recommendations

Several recommendations were made to the Allen County board of commissioners. These recommendations resulted from the engi-

TABLE _____ SHEET NO. _____

PRIORITY RATINGS FOR _____ (CLASSIFICATION) HIGHWAYS IN NUMERICAL ORDER

_____ COUNTY

1. RANKING NUMBER	2. PRIORITY RATING	3. HIGHWAY NUMBER OR NAME	4. LOCATION	5. LENGTH (MILES)	6. SERVICE RATING	7. ROAD RATING	IMPROVED TO MINIMUM STANDARDS			NEW OR RECONSTRUCTION TO DESIRABLE STANDARDS		
							8. ESTIMATED TOTAL COST (DOLLARS)	9. SERVICE UNIT COST COL. 8 / COL. 6 DOLLARS	10. COST PER MILE COL. 8 / COL. 5 DOLLARS	11. ESTIMATED TOTAL COST (DOLLARS)	12. SERVICE UNIT COST COL. 11 / COL. 6 DOLLARS	13. COST PER MILE COL. 11 / COL. 5 DOLLARS

FIGURE 5.

neering analysis. They included the suggestion that the various classification systems be adopted as designated in the study.

The commissioners were reminded that the numerical priority rating should be used as an administrative guide to indicate highway sections of highest need for improvement. As county officials, they still must exercise good judgment in the determination of the total amount of funds to be spent for each of the three classification systems as well as the selection of individual maintenance and reconstruction projects on an area or cost basis.

Inasmuch as the engineering analysis did not include an inventory and evaluation of the local service highways, it was recommended that the Allen County officials initiate such a program as soon as possible.

It was also recommended that a program of periodic classified traffic volume counts be established to keep the traffic volume data up to date.

Another recommendation urged a periodic resurvey of the county highway system at no more than four-year intervals. Such re-evaluation would enable officials to determine new priority ratings and new rankings of the various highway sections.

It would also enable county officials to determine the progress of their highway improvement program provided adequate construction, maintenance, and fiscal records are also available.

Another recommendation advised that all future maintenance, reconstruction, and construction costs be governed by the design policies presented in the Allen County study.

The Joint Highway Research Project of Purdue University appreciated the opportunity to participate in the engineering analysis, the first study of this type to be made in the State of Indiana.

Ready cooperation extended by the board of commissioners of Allen County, Indiana, and the many other public and private agencies is also acknowledged.

Internally-Illuminated Traffic Signs

ROBERT J. NEU

Mr. Neu has served for the last several years in various capacities in acrylic plastic development work with the Rohm and Haas Company, chemical and plastics manufacturer. He has participated in research and development of the acrylic-type sign with numerous governmental agencies and private engineering consultants.

WHEN a confused motorist slows down in the midst of heavy traffic to try to find his way, complexity or overabundance of highway signs can be dangerous. At night the danger is multiplied.

The function of traffic signs is becoming increasingly critical as more and more automobiles take to the road and more and more multi-lane expressways are built. The speed and volume of traffic, and the complex interchanges on our thruways and expressways require signs which must be recognized and understood at a glance, both day and night.

Many of the federal, state and local agencies responsible for the purchase of highway signs are now re-examining their standard sign programs. A recent survey by the New Jersey State Highway Department, for example, revealed that nearly 70,000 direction signs in that state are too small, too cluttered or badly placed.

As one result, the department is removing signs along more than 1,700 miles of state roads and replacing them with about half the original number, located so that even a stranger can find his way without stopping at intersections or creeping at interchanges. In addition, signs now listing eight to twelve near-by communities are being replaced by signs bearing the title of a single municipality or area.

Luminous arrows replace the old delineators. Acrylic plastic signs with interior lighting replace unlighted directional signs at many heavily-used intersections. Overhead signs formerly lighted by exposed tubing are also being replaced by back-lighted acrylic signs in some cases.

Proper night-time illumination is one of the key factors in the New Jersey sign improvement plan, as it must be wherever traffic

authorities are faced with growing volumes of after-dark traffic. Signs with good readability both day and night are essential.

Three Types of Illumination

Over the years traffic engineers have developed three basic methods for illuminating highway signs. The first method, chronologically, was the use of exposed light elements, either in some variation of the gooseneck fixture or as exposed incandescent lamps or neon tubing. The next technique to achieve practical application was the reflection method, depending upon automobile headlights for activation. The third method, largely developed during the last five years, uses interior lighting in conjunction with translucent acrylic plastic sign faces.

This article describes briefly the general post-war development of acrylic signs and their characteristics, and in more detail the factors of legibility, lighting, color and location as applied to internally-lighted traffic signs.

Development of Acrylic Signs

The development of acrylic plastic traffic signs has been one of the side benefits of a major advertising "revolution" now in progress. This change got under way at the close of World War II. It has affected both national and local advertisers and is being widely used in merchandising. Evidence of this can be seen on almost any business street.

Just as neon caused a major sign revolution in the pre-war period, so the use of acrylic has become the major outdoor sign development since the war. Acrylic plastic was pioneered in the United States in the late thirties. Best known under the trade name Plexiglas, it was first used in large quantities, other than in aircraft, for indoor signs where its ease of fabrication and clear brightness made it popular for point-of-display signs of all kinds.

After the war-time demand for Plexiglas aircraft enclosures eased in 1946, the first significant sign application was by nationally-known companies which used quantities of identical acrylic signs outdoors to identify their dealers. From quantity signs, the use of

sheet acrylic spread rapidly to the field of custom signs and to other indoor and outdoor applications, such as its use in molded form for automobile tail lights and trademark medallions used to identify various makes of cars.

Characteristics of Acrylic Signs

Other types of translucent plastics have been extensively tested for outdoor use but none have approached acrylic in long-term resistance to weather exposure and the degenerative effects of sunlight. In consequence, its use has increased where outdoor signs are concerned.

Characteristics of the new material include light weight (less than half the weight of glass), dimensional stability, shatter resistance, and excellent light transmitting and diffusing properties.

The color pigment is dispersed throughout the sheet, eliminating the need for periodically retouching or repainting the sign face. The sign retains the same bright color and clean appearance in daylight as when lighted at night. Because of the even diffusion of light throughout the plastic face, it gives a strong visual impact at night and eliminates much of the nighttime garishness and strong halation effect. Lack of exposed light elements enables it to achieve a dignified and pleasing appearance in keeping with modern design trends.

Acrylic sheet can be sawed, drilled and cemented. When heated it has the consistency of a sheet of rubber and can readily be formed into desired shapes. On painted versions, legends are either silk-screened or sprayed. The sign can be illuminated by almost any light source.

Once installed, they are economical to maintain and sign failures are reduced to a minimum since the shatter-resistant plastic protects the light elements from weather and vandalism. If one of the light elements fails, the message of the sign remains visible because the remaining light is diffused across the entire face.

The Port of New York Authority has used illuminated acrylic for directional signs on expressways, tunnels and bridges in the Metropolitan New York area. The new signs consist of a metal light box faced with a white translucent acrylic panel on which the legend has been painted.

Advantages of backlighted acrylic signs take on added significance in the traffic field. For example, reduction in the nighttime halation effect characteristic of signs with exposed light elements results in improved long-distance legibility for the motorist.

A factor that must be considered in any type of electric sign is the chance of power failure, which could cause the sign to lose all effectiveness at night. This, of course, is one of the major reasons for the current popularity of the reflective-type sign. There are many areas, however, where electrically-illuminated signs fill a definite need. One example is where there is a high incidence of competing light and another is in an area where the motorist has a short viewing distance, as when the sign is placed shortly after a sharp or abrupt curve.

Legibility Factors

As in the case of conventional highway signs, legibility is a most important consideration in the design and location of illuminated signs. The confused motorist often becomes a major hazard in day or night traffic. Many traffic signs are too small and the motorist has to slow down or stop to read them. Meanwhile, traffic piles up.

In the New Jersey survey, nearly 70,000 signs were found to be small, cluttered with lettering, or badly placed. As a result of this survey and other similar surveys, it seems safe to predict that traffic authorities in the future will insist on fewer and larger signs, with more legible messages, and in better locations.

Many factors which influence legibility in the conventional unlighted sign also apply to the luminous sign. These factors include copy, letter style, letter dimensions, lighting, color and location.

Simple Sign Copy More Effective

There are no set rules on copy for internally-lighted signs, other than the general rule: the more limited the copy, the more effective the sign. The trend today is away from listing a large number of destination names at busy interchanges. The listing of one general community or the name or number of a highway has been found adequate and causes less confusion for the motorist.

Proper spacing of letters is important and is often overlooked in the design of traffic signs. At certain distances from the human eye, parallel lines merge and appear as one line. Therefore, after letter height is determined, care must be used in spacing the letters in relation to the distance from which they will be viewed.

This is necessary because the normal eye cannot differentiate below one minute of arc. If we consider the letters of the sign as located on the circumference of a circle with the motorist at the center of the circle, all letter lines must have a separation of not less than one-sixtieth of a degree. The calculation for this separation, expressed mathematically, is

$$S = 0.0035D$$

where S is the separation in inches between letter lines and D the distance in feet from the letters to the motorist. The maximum clear-viewing distance desired between the motorist and the letters is measured and multiplied by 0.0035. If the motorist is to read the sign from 1,000 feet away, the spacing between the letter lines should not be less than 3.5 inches. This calculation is for non-illuminated letters.

In illuminated signs with exposed lighting elements, the halation given off by the luminous units must be taken into consideration and the minimum spacing must be at least doubled. When halation is reduced and readability increased, the spacing in the example could be less than seven inches and preferably in the range of five inches to six inches.

Letter Style and Dimensions

The style of letter employed is also an important factor in sign legibility. In commercial signs, designers frequently stray from the ultimate in legibility to achieve a unique or special effect in lettering. Such originality, however, is unnecessary and undesirable in traffic signs. In general, the most legible letter style is the standard block letter with a width three-fifths the height and a stroke of 15 percent of the height.

The relative legibility of the various letters of the alaphabet is also a factor in the legibility of internally-illuminated traffic signs.

When using standard block letters with an approximate height-to-width proportion as given above, the letter A and I will be the most legible letters and B, G and H will be the most difficult to distinguish.

In the following relative legibility table the letter E has been taken as unity since it is the most frequently used letter:

A–1.30	F–1.04	K–1.05	P–1.04	U–1.07
B–0.85	G–0.92	L–1.19	Q–1.05	V–1.03
C–1.07	H–0.92	M–1.13	R–0.97	W–1.13
D–1.03	I–1.41	N–1.00	S–0.95	X–1.08
E–1.00	J–1.04	O–1.05	T–1.15	Y–1.04
				Z–1.01

For complete legibility, the minimum size of letter to be used in a sign should be determined wherever practicable by the relative legibility values of the particular letters appearing in the sign.

Color and light also will have a determining effect on legibility at stated distances. The acrylic letter, whether flat or formed, can be obtained in a variety of colors and can be made to glow with light over its entire surface. It preserves its formal integrity in this way when lighted at night.

Because of the variables involved in traffic signs, it is probably impossible to determine letter height to the exact fraction of an inch for best readability at given distances. Laboratory tests have shown that a good rule-of-thumb formula for determining letter height with relation to readability is:

$$\text{Letter height in feet} = \frac{\text{Distance letter is to be legible}}{440}$$

This formula would mean that legibility at 1,000 feet, the minimum letter size should be two feet, three inches. This has proved to be a safe formula, perhaps a conservative one, and an excellent general rule since safety is paramount in the design of traffic signs.

Caution should be used concerning test methods where a highway agency is evaluating the legibility of signs. It is difficult to duplicate in walking tests the problems of readability under actual driving conditions. Tests should, of course, depend upon the observations of several people rather than upon an individual. Inter-

changeable letters should also be used so that the observer does not know which letters are being displayed. It is easy for an observer to think he can read a letter when he knows which letter is being displayed.

Lighting

Visibility and legibility are of equal importance in an illuminated sign. In general, luminosity increases one and decreases the other. That is to say, the greater the luminosity, the greater the visibility but the lower the legibility. The successful traffic sign is one which strikes the best balance between these two factors.

In the panel sign, acrylic is used for the face or as a background for acrylic letters. The principal light sources for these backlighted signs are slimline fluorescent lamps and cold cathode lamps.

The recommended slimline lamp is the standard hot cathode combination. This is made by several manufacturers and has an instant-start filament and a special high voltage ballast for operation outdoors. The 37 mm. diameter (T-12) lamp operated at 430 ma. is the most common hot cathode lamp used for acrylic signs.

Cold cathode lamps are available in standard straight lamp lengths and diameters and in standard "hairpin" shape. Ballast currents are generally 120 ma. and 200 ma. Special cold cathode lamps (neon type) are also used in backlighted signs, usually in 9 mm. to 15mm. diameters, and at currents of 30 ma. to 120 ma.

It may not be possible in designing internally-illuminated traffic signs to incorporate lighting which will meet the ultimate requirements of all types of traffic districts. However, within reasonable economic and design limitations, the amount of light is important to the legibility of the sign. The main question in lighting is, therefore, how bright the sign should be. The answer depends to a large degree upon the brightness of the area in which the sign is to be located. The sign industry recognizes three classes or districts of brightness: high, medium and low.

High districts are downtown locations with high levels of illumination from street lights, store windows and heavy sign concentrations (200 to 350 foot lamberts). Medium districts are suburban areas with reduced levels of illumination from street lights and store

windows, and with only moderate sign competition (150 to 200 lamberts). Low districts are rural areas or locations with no lighting competition (90 to 150 lamberts).

When the colors for acrylic backgrounds are used, a formula for determining the number of lamps of a given type required to achieve the recommended brightness in the three brightness districts is as follows:

$$\text{Number of lamps required} = \frac{B \times A}{MF \times E \times L}$$

where B is the brightness required, depending on the district; A is the total luminous area of the sign; MF is the maintenance factor (average of 70 percent); E is the light transmission efficiency factor of the acrylic sheet (average of 80 percent for double face signs, 60 percent for single face signs); and L is the number of lumens per lamp (from tables supplied by lamp manufacturers).

The above percentages for light transmission efficiency are based on a light-reflecting value of 75 percent on all surfaces inside the sign box. Usually unfinished sheet metal will meet this requirement. If it does not, the interior surfaces should be painted a reflective white.

Assume a double-face acrylic panel sign is to be designed for installation in a high brightness district and that 350 foot lamberts will be required. Each panel is to measure 48 inches x 72 inches. The problem is to determine how many 72-inch T-12 warm white slimline lamps operated at 430 ma. will be required. (B = 350, from brightness table; A = 4 feet x 6 feet x 2 faces = 48 square feet; MF = .70; E = .80; L = 3600, from figures supplied by lamp manufacturer. The number of lamps required =

$$\frac{350 \times 48}{.70 \times .80 \times 3600} = 8.2 \text{ or } 9 \text{ lamps.)}$$

Two dimensions are significant in the proper layout of individual lamps. They are the spacing between the lamps and the spacing between the lamps and acrylic faces. These dimensions are related and must be considered together in designing the lamp layout for uniform distribution of light over the sign face. A simple rule that should be followed is: "The distance between the lamps and the acrylic should be equal to the distance between the lamps them-

selves, but never less than one-half the distance between the lamps."

For example, it is determined that nine warm white T-12 slimline lamps operated at 430 ma. would be required to obtain a brightness of 350 foot lamberts in a 48-inch by 75-inch double-face sign. The rule on lamp spacing should now be applied to this sign to assure uniform surface brightness over the plastic faces. By dividing 10 (the number of spaces) into 48 inches, it is found that the lamps should be on 4.8-inch centers. Using the 1:1 ratio, it is determined that the lamps should be 4.8 inches away from the plastic faces.

As another example, let us assume that only five lamps are required in a low brightness district. Dividing six (the number of spaces) into 48 inches (assuming the same size as in the previous example), it is determined that the lamps will be located on 8-inch centers. The lamps should preferably be located eight inches, but not less than four inches, from the acrylic faces.

Signs designed to use standard lamps will have more uniform surface brightness if the lamp sockets are located outside the translucent area in the edges of the sign. Otherwise there will be some falling off of light in the face directly over the lamp sockets.

Color

When the matter of color is considered, the question is always raised as to whether dark letters on a light background are more efficient than light letters on a dark background. A study of the legibility of backlighted Plexiglas traffic signs was undertaken recently to determine answers to this question under specific conditions. Tests were performed under conditions which simulated highway situations where considerable competing background light would be encountered. These tests indicated that best results are obtained by using black opaque letters on a light background under both day and night conditions. However, as indicated below, these results should not be generalized to apply to all types of conditions.

Cold cathode lighting was used, and the brightness of the white background reached a point somewhere between 30 ma. and 60 ma. of power input when legibility passed its peak and started to decrease. The legibility of the letters also remained good down to the threshold of lighting at 38 volts, where the tubes would barely re-

main evenly lighted. The latter condition indicated that a back-lighted sign would be legible under adverse weather conditions where the temperature would tend to reduce the light output of the tubes.

In these tests, a sheet metal sign box with the interior painted white and with a 20-inch x 40-inch opening, was set up at the end of a level walkway approximately 1,000 feet long. The front of the box was faced with Plexiglas sheets of various colors which were interchangeable with each other, and the box was lighted with two six-foot 25 mm. cold cathode hairpin tubes. A set of test conditions would be set up as the observer walked to the far end of the test range. He would then turn and approach the testing station until a point was reached where the letters were legible.

It should be pointed out that the results of these tests did not show a decided difference between the two color combinations for all types of conditions. The results were limited to the specific conditions of strong competing background light. Through the years a number of studies have been made by various authorities on the general problem of legibility, and the concensus appears to be that a light letter on a dark background offers the best legibility, all other conditions being equal.

Again, however, there will be specific areas where a luminous light background with dark letters will give an advantage in legibility. An example of such an area would be a sign location with a background consisting of numerous spot sources of light such as street lamps. An illuminated letter on a dark background could lose most of its legibility here because it would not have sufficient contrast to the spot sources in the background.

Tests have been made on this subject by other organizations. One series by the Civil Aeronautics Administration provided some helpful information which has a bearing on automobile traffic. This is reported in detail in the C. A. A. Technical Development Report No. 170, entitled "The Development of Airport Taxi Guidance Signs." In daytime experiments this study found that a yellow letter on a black background always appeared smaller than the same letter in black on a yellow background and that the black on yellow was easier to read. The black on yellow also stood out better against the background.

FIGURE 1. Delaware's overhead signs are internally lighted with neon tubing. The acrylic letters are completely luminous and glare-free.

FIGURE 2. Acrylic signs for traffic direction in Delaware. The letters are 24 inches high and are formed from translucent yellow acrylic plastic. They are mounted on blue porcelain backgrounds supported by highway sign bridges.

When comparing black on white with black on yellow, observers preferred the latter which they claimed was less glaring and easier on the eyes when observed in bright sunlight. With light snow on the ground, the yellow signs were much more noticeable. By using a yellow background, the brightness of which is greater than the normal surroundings, it is not necessary to provide extra background area on the sign above and below the letters. If a light letter on a black background were chosen, it would be necessary to provide materially greater area for the background. In general, there is a tendency for dark signs to lose themselves in neutral surroundings rather than to stand out from it as in yellow or white signs.

In C. A. A. tests to determine relative reading speeds, it was found that black on white was read 16 percent more rapidly than white on black. Green on white, blue on white, and black on yellow were read almost as quickly as black on white.

In contrast, the C. A. A. study concluded that best nighttime results could be obtained with a yellow luminous letter on dark opaque background.

One important point, regardless of legibility of the various systems, is that a sign with a luminous light area for a background has better target value than the dark background sign. It tends to attract the eye to the sign, which emphasizes that a sign must be seen before it can be read.

Location of Signs

Proper location of a traffic sign is vitally important to its effectiveness. The leading questions in this area center around the problem of whether overhead or shoulder type signs are most effective.

The general consensus leans toward overhead signs, installed on sign bridges or wires, for greatest effectiveness on multi-lane highways. The reason, of course, is that these signs are less subject to obstruction by trees, shrubbery and parked cars; they are also visible to all approaching traffic in all lanes.

On the conventional two-lane highway, there is less reason for overhead signs except, perhaps, in congested urban areas where signs at the side of the street might be lost in a maze of commercial obstructions.

Internally-illuminated signs can, of course, be mounted at any desired height since they are not dependent on automobile headlight beams for their effectiveness.

Day Legibility Versus Night Legibility

The writer has made a study of shopping habits and comparative volumes of day and night traffic in commercial centers in an effort to obtain a better picture of the relative importance of daytime legibility versus night legibility. The study was primarily intended to relate to commercial signs, but the findings are also applicable to traffic signs.

To draw general conclusions on the subject of traffic densities is extremely difficult because of variables both within a city and between different cities. Each traffic problem is highly localized. However, the response to our inquiries from a variety of sources was consistent enough to show that traffic today is still predominantly a daytime problem throughout the country.

One governmental authority states that 55 percent to 65 percent of weekday travel in an entire urban area occurs between 7 A.M. and 6 P.M. This same study shows for two specific cities a ratio of 69 percent to 31 percent and 73 percent to 27 percent in favor of daytime traffic.

A national marketing group study shows that from 66 percent to 81 percent of department store purchases are made in daytime hours. The percentage varied according to location and city.

In one city a study made by an outdoor advertising group found that daytime traffic passing certain prominent locations predominated over nighttime traffic by 87 percent to 13 percent. An automobile association uses a rule-of-thumb ratio of 75 percent day traffic to 25 percent night traffic. A safety foundation reports the same 75 to 25 ratio and states that the daytime percentage is closer to 80 percent in larger cities and nearer to 70 percent in smaller cities.

These figures are cited here to emphasize the fact that with the growing demand for lighted traffic and directional signs, emphasis must be placed on the importance of achieving the illuminated effect without sacrificing daytime legibility. The electric sign must be a

good "daytime reader" as well as a "nighttime reader," since the majority of motorists see and use the sign in the daytime.

The internally-illuminated sign readily lends itself to this situation since it is clearly legible during the day. At night it can be brightly illuminated if necessary; more important, however, it can be illuminated with a lower scale of intensity than is possible with exposed light sources. It is therefore possible to obtain maximum legibility around the clock with the same sign and obtain better control of nighttime legibility at the same time. The problems of shadows cast by exposed fixtures and glare caused by the intensity of exposed light sources is also eliminated.

In all studies of problems relating to traffic signs, those concerned should be thoroughly familiar with the research done by the Bureau of Public Roads, Department of Commerce, and published in their booklet "Standard Alphabets for Highway Signs." In the preparation of this article we are also indebted to Texlite, Inc., sign manufacturers, from whose studies on legibility we have obtained the formula on proper spacing of letters and the relative legibility table. Finally, we are indebted to the Civil Aeronautics Administration's work on taxi guidance signs.

Technical assistance is regularly being extended to sign companies and highway agencies by design and fabrication consultants, and it is hoped that the developmental work being done by these laboratories will continue to be useful to traffic engineers in planning the signing of our present and future highways.

Seattle's Curb Parking Rate Change

E. E. LEWARCH

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SEATTLE, the largest city in the Pacific Northwest and the third largest city in the eleven western states, has a metropolitan area population of three-quarters of a million, 550,000 of whom live within the city limits. Vehicles registered in the city increased at an average rate in excess of 6 percent a year for the last fifteen years—from 125,000 registered in 1940 to nearly 250,000 in 1955.

The increase in population and vehicle registration in the area, and the constant decrease of curb space available for parking in the central district due to the allocation of additional curb loading space, have intensified the critical parking problem.

Off-street parking facilities, constructed and operated by private enterprise, have not increased sufficiently during the last decade to alleviate the problem. Thus the maximum possible turnover must be obtained in the available curb parking space.

Increased Turnover

The first step to provide increased turnover in curb-parking spaces came in 1942 when Seattle installed 1600 parking meters in the central business district. Previous studies of meter installations in other cities indicated the automatic type of meter operation by far the most satisfactory. The generally accepted meter-rate then was a nickel an hour, with the use of space limited to one hour.

Central business district merchant groups, as well as other organizations, strenuously opposed the original meter installation. They argued that a fee for parking on public street areas violated stipulations in the legislation dedicating such areas for public use. They

said that charging a fee would drive parkers from the area, causing decentralization and economic disaster.

Various user-groups added that the vehicle owner, already bearing an excessive tax burden, would suffer an injustice through an additional fee for the "right to park." These groups, evincing an interest in the use of funds from parking meters, were later instrumental in obtaining legislation requiring that all revenue from parking meters be expended for traffic purposes.

Studies of curb space, conducted before and after meter installation, showed that the meter installation increased by approximately 30 percent the turnover of parking spaces on the street, and eliminated the majority of overtime parking prevalent in the area. The police reported they could do a more efficient enforcement job. Motorists parking in the area were able to find parking spaces more readily, and merchants found their business *increasing*.

As a result of the success of the meter operation in the central district, the community clubs and commercial clubs of the various suburban shopping districts requested the installation of meters in their areas so that at the present time some 4600 parking meters operate in Seattle. Increased demands in the central district resulted in additional installations, increasing the meters from the original 1600 to 2800 meters in an expanding area. The myth of decentralization of the central district is definitely exploded.

In 1946, the Seattle Engineering Department in cooperation with the Bureau of Public Roads and the Washington State Highway Department, conducted a comprehensive study of parking in the Seattle central business district to:

1. Obtain a record of the number of cars that could be accommodated in existing curb and offstreet parking facilities; 2. arrive at an estimate of the additional facilities needed, and 3. determine the proper location and type of facilities that would best serve a majority of the downtown parkers.

Revealing Survey

The survey found a total of 206,800 vehicles entering or leaving the central district between 9 A.M. and 6 P.M. on an average week day.

Of these vehicles, 76 percent were passenger cars, 16 percent, trucks, 4 percent, buses, and 4 percent, taxicabs.

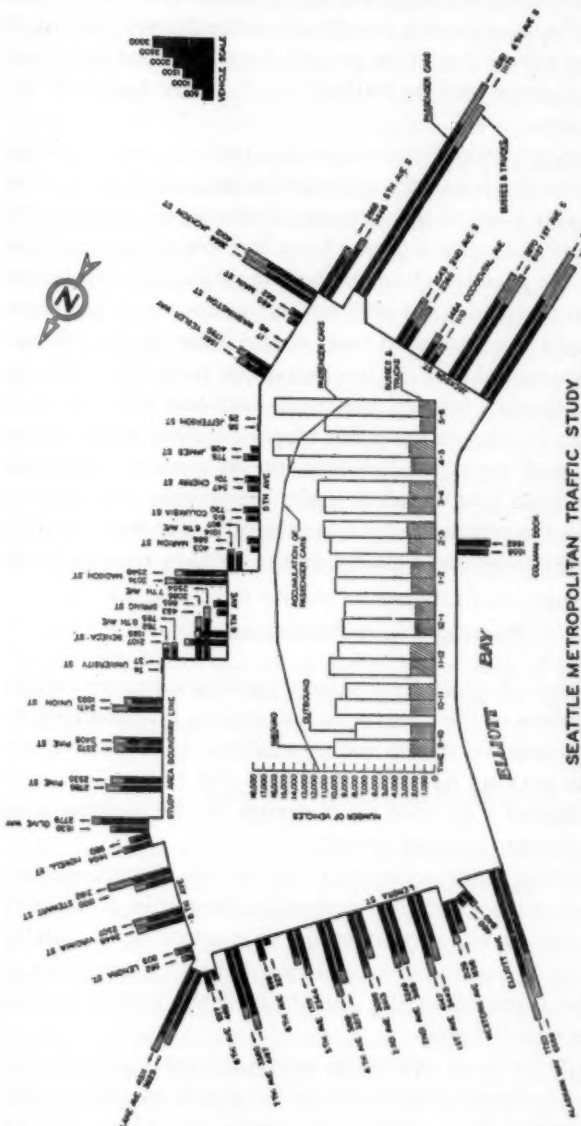
Approximately half of the passenger cars entering the area, some 40,000, did not stop to park and could have used by-pass routes if such had been available. The major portion of the passenger vehicles parking in the area, approximately 65 percent of those parking, parked in curb spaces of which nearly one-half were metered spaces. Only 18 percent of the vehicles parked in parking lots and 17 percent parked in parking garages.

The number of curb spaces available for parking at that time was substantially the same as in 1942. However, the installation of parking restrictions between 4 p.m. and 6 p.m. on many of the downtown streets to relieve peak traffic congestion reduced the space hours available for parking between 9 a.m. and 6 p.m., when the meters operate.

Thus, at the time of the survey, there were 3,800 spaces available for parking at the curb in the central district. Of these, 1800 spaces were metered spaces limited to sixty minutes of parking for one nickel, and 2000 were spaces where posted signs limited the duration of parking to one hour, but parking meters were not in operation. At approximately 300 of the metered spaces, parking was prohibited between 4 p.m. and 6 p.m. and an equal number of unmetered spaces were similarly restricted. Thus a total of 33,000 space hours of parking were available in the 3800 curb spaces during the period from 9 a.m. to 6 p.m., and only 15,600 of these space hours were controlled by parking meters.

The survey showed a total of 26,000 vehicles parked at the curb, an average turnover of seven cars per parking space during the nine-hour survey period for the entire central district. An analysis of the 15,600 space hours of metered curb space showed an average turnover of 8.5 cars per parking space during the nine-hour period, indicating the increased use because of the high level of enforcement obtainable with meter installations.

The average length of time parked at the curb was sixty minutes for the entire survey area, while the average duration in metered spaces was forty-five minutes. This relatively short time period of parking in metered spaces where a longer time period was permitted, and was paid for by the parker, was best explained by the fact that



SEATTLE METROPOLITAN TRAFFIC STUDY
CENTRAL BUSINESS DISTRICT PARKING SURVEY

NUMBER OF VEHICLES ENTERING & LEAVING
THE CENTRAL BUSINESS DISTRICT ON A WEEKDAY
BETWEEN 9:00A.M. AND 6:00P.M.

sixty percent of the parkers at the curb gave business as the purpose of their trip and approximately two-thirds of the drivers parking to transact business parked for a time period of less than one hour, and three-quarters of these parkers walked less than five hundred feet to their destination.

The purchasing power of the nickel in 1946 was somewhat less than in 1942. However, it had not decreased to its level of subsequent years. Also, the rate charged by operators of off-street parking facilities for parking time in excess of one hour had not substantially increased, so that the practice of meter feeding to illegally extend the parking time in metered space had not as yet become a problem. However, by 1952 the increased rates charged for parking in off-street facilities compared with the low rate of one nickel for one hour of parking time charged for parking at the curb had resulted in an increase in meter feeding to the point where a serious enforcement problem confronted the police department. As a result, the traffic engineering division conducted a study of parking duration in metered space in the central district to determine the warrant for a change in the fee charged or a change in the parking time limit, or both.

Parking Times Discovered

During the summer of 1952 field studies of parking turnover showed that over 50 percent of the parkers in the central business district parked for thirty minutes or less and approximately 80 percent left their cars in the parking spaces for less than one hour. Such curb space usage indicated a warrant for a change in the parking time allowed and in the rate charged as well.

After considering the experience of cities where adjustments had been made in meter rates and after evaluating the results of the curb space usage studies, it was recommended that a rate of one nickel for one half-hour of parking time and two nickels for one hour of parking time be initiated in the operation of the Seattle central business district metered area.

It was urged that such operation would properly provide for those parkers whose requirements demanded a parking time period in excess of one-half hour while adequately providing for the majority of the parkers whose requirements were satisfied by a half-

hour period. In addition, the increased rate from one nickel for one hour to two nickels for one hour would reduce to some extent the meter feeding, which was observed to be on the increase.

Unexpected support for the proposal was received from the operators of off-street parking facilities, who were aware of the abuses of the existing meter operation. In addition, the majority of curb parkers who desired to park for a short time lent their support realizing that such an operation would result in an increase in available parking space and thus reduce the amount of time spent in searching for a parking space in the central area.

After due consideration of the arguments for and against the change, the City Council approved the plan and in 1953 some 2,500 parking meters in the central district were revised to provide for the new operation. The motoring public accepted the change with practically no objection and no detrimental effect on business in the area was observed. Operation under the new method proved such assumptions were false. The revenue from the central business district meters increased some 75 percent after the new rate was put into operation from $210,976.75 in 1952 to $369,455.65 in 1954.

The revenue from meters in 1952 had decreased some $10,000 from the 1951 revenue. This would indicate a detrimental effect to the district from 1951 to 1952 due to the lack of available parking space for short-term parking resulting from the parking rate of one nickel for one hour of parking time.

Rate Change Proves Successful

Field checks of parking habits in the area after the rate revision show an increased percentage of short-term parking from the 55 percent observed before the revision to a duration of thirty minutes or less by 65 percent of the parkers two years after the change in rate was made. As a result of the observed success of the rate change in the central district, field studies were conducted in metered areas in suburban business districts to determine the need for changes in those areas. These studies showed that in most areas the parking time limits in the core of the district did not warrant any change from the rate of one nickel for one hour parking. However, the meters in the fringe area did not receive proper use with such a rate.

Passenger Cars Entering and Leaving Parking Spaces in Central Business District

Time of Day	*Entering*	*Leaving*	*Accumulation*
Before 9:00 a.m.	3,916	...	3,916[1]
9:00 to 9:30	4,424	838	7,502
9:30 to 10:00	2,253	1,500	8,255
10:00 to 10:30	2,313	1,810	8,758
10:30 to 11:00	2,387	1,974	9,171
11:00 to 11:30	2,286	1,953	9,504
11:30 to 12:00	2,346	2,197	9,653
12:00 to 12:30 p.m.	2,295	2,116	9,832
12:30 to 1:00	2,000	1,981	9,851
1:00 to 1:30	2,114	2,123	9,842
1:30 to 2:00	2,072	2,179	9,735
2:00 to 2:30	2,114	2,204	9,645
2:30 to 3:00	2,031	2,307	9,369
3:00 to 3:30	1,927	2,310	8,986
3:30 to 4:00	1,781	2,422	8,345
4:00 to 4:30	1,289	2,649	6,985
4:30 to 5:00	1,191	2,051	6,125
5:00 to 5:30	1,057	2,560	4,622
5:30 to 6:00	610	2,003	3,229
After 6:00 p.m.	...	3,229	
Total	40,406	40,406	3,229[2]

[1] Cars parked at curbs and in lots and garages at 9:00 a.m.
[2] Cars left parked at curbs and in lots and garages at 6:00 p.m.

A detailed analysis of the field data indicated a warrant for an increase in the parking time from a one-hour limit to a two-hour limit in all fringe areas. Subsequently the meters in these areas were adjusted to provide one hour of parking for one nickel or two hours of parking for two nickels. An immediate increase in usage of the spaces in these areas was observed and favorable comment was received from the general public and business groups in the areas affected.

During the last few months there have been installed additional revisions of parking rates at certain locations in the central district to increase the space available for short-term parking. Spaces adjacent to banks and the first meter space adjacent to intersections have been converted to a rate of one nickel for fifteen minutes of

parking time with the legal parking time limited to a maximum of fifteen minutes. This adjustment was made to serve the demands of parkers stopping for business purposes the nature of which requires little time to complete. Here again favorable comments have been received from businessmen in the area as well as from the motoring public.

Experience with parking meter rate changes indicates a need for the proper evaluation of the trip purpose of the parker to determine the proper rate and time limit. In general, one who parks to conduct business places a higher premium on curb space than one who parks for other purposes. Also, one who parks to conduct business requires a shorter time for parking than other parkers. As experience with changes in parking meter rates already in effect is evaluated, further revisions in parking meter operation to serve properly the needs of parkers appear to be warranted.

Philadelphia's New Program for Traffic Signal Modernization

STEPHEN F. BUTTERFIELD

Mr. Butterfield has been City Traffic Engineer of Philadelphia, since 1953. A 1939 graduate of the Yale Traffic Bureau, Mr. Butterfield has extensive experience in traffic engineering and highway transportation. He acquired extensive highway engineering and administrative experience in the state highway departments of New Hampshire and Connecticut. Preceding World War II, he was State Traffic Engineer in Connecticut. In addition, Mr. Butterfield has extensive experience in military transportation matters. Mr. Butterfield is a member of the American Society of Civil Engineers, the Institute of Traffic Engineers, and the Society of American Military Engineers. He is a registered Professional Engineer in Connecticut and the District of Columbia.

PHILADELPHIA recently began a major revitalization of its antiquated traffic signal system. Other major metropolitan areas may find themselves confronted with somewhat similar problems and, therefore, perhaps a recounting of Philadelphia's experience and trials may be of assistance.

Philadelphia's first traffic signal was installed in 1923 at an outlying location on Frankford Avenue, then one of the city's major traffic arteries. This installation at the intersection of Frankford Avenue and Orthodox Street was of the single mastarm type with a four-faced pendant unit. Although this unit has since been replaced, because of the installation and passage of the Frankford Elevated structure through this intersection, innumerable similar installations made subsequently, still exist throughout Philadelphia.

Significantly, even though motor vehicle registration in Philadelphia during the intervening years has mushroomed from 198,000 to 502,000 vehicles, today the traffic volume through many of these intersections falls short of normal requirements for fixed-time traffic signal installations.

Since 1923 the number of signalized intersections in Philadelphia has grown from that initial installation to a mammoth sys-

tem of 2,064 signalized intersections. Table 1 indicates the year by year installation of traffic signals and the continuous growth of the system. Much of this haphazard increase may be attributed to the city's fluctuating financial status throughout the ensuing 33-year period.

Inadequate Signal Maintenance

The spasmodic growth of Philadelphia's signal system, which resulted from the non-uniform yearly appropriation of funds for new installations, greatly handicapped the healthy growth of the system. In addition, funds available for maintenance were entirely inadequate. Indeed, the city traffic engineer normally had neither the required funds nor sufficient signal maintenance personnel to perform even the most basic preventive maintenance measures on the installed traffic signal equipment.

With increasing frequency as the original equipment aged, essential bearings and other moving parts of the signal controls became non-serviceable. Even without actual motor failure this lack of maintenance resulted in unacceptable signal timing variance, thus effectively nullifying pre-established signal cycles and offset timings. Indeed, the shortage of maintenance crews became so acute that the elementary work of cleaning lenses and reflectors and the periodic replacement of lamps on an average life basis became impossible. As a direct consequence, it was not infrequent to find scores of intersections along a single traffic artery at which one or more burn-outs existed.

Likewise, throughout the years motor repairs and replacements were accomplished on a minimum basis; and not infrequently a signalized intersection would remain dead for several weeks until such time as replacement parts could be crudely manufactured at the signal shop by the adept maintenance crews.

Indeed, this lack of essential signal maintenance was the general situation up to less than three years ago. In 1952 the new city administration appropriated increased funds for use in the purchase of replacement signal motors, equipment and parts. Similarly, a slight increase of funds was provided to cover the salaries of additional signal repair personnel.

TABLE I

Yearly Installation of Traffic Signals in Philadelphia

1923–1955

Year	*New Signals*	*Total Signals*	*Year*	*New Signals*	*Total Signals*
1923	1	1	1940	43	830
1924	19	20	1941	55	885
1925	20	40	1942	26	911
1926	35	75	1943	6	917
1927	23	98	1944	5	922
1928	73	171	1945	7	929
1929	66	237	1946	15	944
1930	166	403	1947	102	1046
1931	48	451	1948	96	1142
1932	43	494	1949	105	1247
1933	24	518	1950	98	1345
1934	15	533	1951	189	1534
1935	30	563	1952	147	1681
1936	42	605	1953	140	1821
1937	108	713	1954	212	2033
1938	65	778	1955	31	2064
1939	9	787			

Analysis of the Problem

The problem confronting the city traffic engineer in 1952 was staggering—the problem of operating and revitalizing approximately 1,534 signalized intersections. This was no easy task since 451 of the signals were over twenty years old, and 885 or 60 percent were ten years old. Since only minor maintenance had been performed throughout the years, the major portion of the traffic signal system was in dire need of major overhauling.

The years 1952 and 1953 approximately may be labeled as the turning point in Philadelphia's traffic signal fortunes. A detailed inventory and analysis of the status of all signalized installations was made at that time. A blueprint was then developed for effectively coping with the overwhelming problem of simultaneously correcting the deplorable status of the installed signal equipment and modernizing the entire system as required by the current and ever-increasing volumes of vehicular traffic.

It was decided to attack the problem on three fronts; namely, (1) correction of prior maintenance deficiencies through a "Program of Deferred Maintenance," (2) correction of normal day-to-day maintenance requirements through a "Program of Scheduled Preventive Maintenance" and (3) correction of the general inadequacy of old signal equipment and installations through a "Program of Signal Modernization."

The successful accomplishment of the modernization program is definitely affected by the success of the deferred and preventive maintenance programs; however, the latter programs will only be described briefly herein. The main purpose of this presentation is to cover those active measures which are being taken in Philadelphia to modernize the antiquated traffic signal system so as to successfully cope with today's increased traffic requirements.

Program of Deferred Maintenance

An initial evaluation of the condition of existing signal equipment indicated varying degrees of deterioration and necessary replacements. It was easily established, however, that one of the greatest deficiencies existed with respect to the old motors of the signal controllers. Not only were these motors so worn they caused slippage, but a majority were not synchronous-type motors. These older motors of the induction type possessed the inherent deficiency of not keeping in step with those at adjacent intersections since they were not responsive to the basic synchronization impulse of the electric power system.

This condition dictated the immediate establishment of a program to replace all existing induction motors with synchronous motors. It was necessary that this should be done as expeditiously as possible. Since the system contained more than 600 signal controllers with induction motors, this program was by necessity spread over a three year period.

The initial motor replacements were in those controllers affecting the operation of progressively timed signal systems. The majority of the remaining induction motors, those located at isolated intersections where their erratic actions had little effect on progressive movements, have now been replaced.

The program of deferred maintenance included extensive replacements of deteriorated traffic signal cable. Extensive repairs throughout the years have been required of the old lead-encased traffic signal cable. Much of this is more than fifteen years old and collection of moisture and its absorption by the non-water resistant filler have caused frequent shorts and cable breakdowns. The current use of thermo plastics for filler and insulation materials to correct this situation was started nearly eight years ago, but the problem is still sizable since Philadelphia still has over one thousand installations to recable.

The replacement of the older type traffic signal heads is also an essential part of the deferred maintenance program. These old heavy castings are not only outmoded and difficult to handle, but since they are not dust proof the reflectors in them rapidly deteriorate. The ensuing 50 percent to 60 percent signal light output is not acceptable.

Program of Scheduled Preventive Maintenance

The prior existence of an effective preventive maintenance program would have precluded the necessity for a deferred maintenance program at this time. The aim of Philadelphia's present preventive maintenance program is to maintain existing equipment on a day-to-day basis so as to eliminate the necessity for major repairs and overhauling at a later date.

The preventive maintenance program includes such normal routine maintenance as periodic motor checks, bulb replacement, lens and reflector cleaning and replacement, painting of signal equipment and replacement of signal wiring. Early each year all motors and moving mechanisms are carefully checked, cleaned and oiled as required. The signal cycle splits are checked and defective motors are replaced. The life of the average motor usually runs up to three years. Bulb replacement is performed on a scheduled basis of 4,000 hours of operation. Signal bulbs are replaced by a specialized crew trained for this work and the cleaning of lens and reflectors.

Signal lenses frequently become pitted and require replacement. When an inspection of the reflectors indicates the deterioration of one or more units the entire signal head is replaced in the field and subsequently rebuilt in the signal shop. The preventive mainten-

ance program has also included the extensive replacement of overhead signal wiring. The older installations consist of double twisted cable; however, replacement is made with nine conductor cable supported by messinger wire. This permits the subsequent modernization of the installation and elimination of the 4-way amber period.

Program of Signal Modernization

In common with practically every large municipality, throughout the years an undesirable number of signals have been installed in Philadelphia on bases other than the standard warrants established by the Manual on Uniform Traffic Control Devices. Unfortunately, a considerable number of such installations have been made despite the best judgment and contrary to the recommendations of the city traffic engineers. Frequently, the sixth warrant of political expediency has prevailed. The damage done to the free movement of vehicles and the congestion thus created, has been an important factor in accentuating the traffic tangle. Although signals had been installed at 1,681 intersections by the end of 1952, yet at that time it was estimated that over 250 such installations could not be justified as fixed-time signals on the basis of the then current traffic volumes. Nearly all such signals had been installed when traffic volumes and other requirements were considerably less. In addition, only five intersections were controlled by vehicle actuating mechanisms, a standard requirement when traffic volumes fail to meet the minimum fixed-time signal warrants.

1. *Vehicle Actuation:* An item of the highest importance in Philadelphia's signal modernization program, therefore, has been the provision of vehicle actuation at those intersections where fixed-time equipment was not originally warranted and at which it cannot be justified today. During the last two years the number of actuated intersections has been increased to 85. However, this figure falls far short of an estimated 400 intersections which would materially benefit from such treatment through minimizing unwarranted delays caused by fixed-time signal equipment.

The average cost of modernizing an unwarranted fixed-time installation by providing actuating mechanism is approximately $1,100. Since the cost of so treating 400 intersections would approxi-

mate $440,000, it is estimated that the correction of this traffic signal deficiency may cover at least a ten-year period. If adequate monies were made available this essential work could easily be accomplished over a three-year period.

It would be desirable, indeed, to remove a sizable portion of those unwarranted fixed-time signals which have been installed throughout the years. There is, however, little hope of this approach. During World War II it was necessary to remove a number of traffic signals in order to provide replacement equipment at other more important locations. Unfortunately, in every case reinstallation of signals at those intersections was forced upon the city's traffic authorities.

2. *Mastarm and Pedestal Replacement:* A second important element in Philadelphia's program of signal modernization has been the replacement of the existing mastarm and pedestal equipment with corner-post installations. The initial signal installations were primarily pendant units suspended from either a single or a pair of mastarm supports.

In addition, a considerable number of pedestal-mounted multi-headed signal units were installed. Since 1938, however, all new installations have been of the corner-post type, providing a double indication for each approach. These latter installations conform to the requirements of the Pennsylvania Motor Vehicle Code.

In 1953, a total of 210 outmoded mastarm and pedestal type signal installations were in operation in Philadelphia. Many of these locations were intermingled with adjacent intersections equipped with corner post units. The effect has been far from desirable. Indeed not infrequently motorists accustomed mainly to corner-post locations, have unwittingly failed to see and observe the overhead signal control indications. The continuation and use of these outmoded installations have been a source of considerable worry to the traffic authorities and the public clamor for their replacement has frequently been heard in the chambers of the City Council.

Unfortunately, funds were not appropriated to facilitate such replacements. The cost of modernizing such installations with corner-post equipment is great. Not only must the old installations be entirely dismantled but there is little of salvage value. Normally, the cost of replacing mastarm or pedestal type installations equals or

exceeds the cost of placing signals at a new location. It has been difficult for the public to comprehend these facts.

As of this date, the city still has 131 mastarm and twelve pedestal signal installations. Although the city has replaced approximately one-third of its antiquated mastarm and pedestal signals since 1952, this program has now virtually halted because of lack of funds for this essential work.

3. *Corner Post Modernization:* Many of the early corner post installations provided only a single signal indication in each direction. They also provided a 4-way amber period and therefore these installations are now entirely inadequate. Replacement of the outdated signal controllers is now necessary and complete rewiring to replace the four wire cable with nine conductor cable. More than 100 signal installations still need such modernization.

4. *Progressive Timing of Signals:* Throughout the last 33 years, the installation of traffic signals in Philadelphia usually has been on an individual intersection basis. Rarely has a simultaneous installation been made of a whole series of intersections along an artery. This piece-meal installation procedure necessarily has resulted initially in an almost complete lack of coordination between adjacent signalized intersections.

Although many of the initial installations were located so far apart as to preclude their being timed for progressive vehicular movement, the subsequent signalization of intervening intersections has not infrequently resulted in an almost continuous series of adjacent signalized intersections. This problem has become especially critical within the last four years with the addition of more than 500 new signalized intersections to the already existing 1,534 controlled intersections.

Thus, the development of time-space diagrams as a basis for providing the most desirable progressive movement travel-band on major traffic arteries has become of prime importance. Since only ten traffic arteries have interconnection by multi-wire cable, progressive movements along all other traffic carriers can only be attained by the provision of offset timing of the adjacent signalized intersection. Synchronous motors are required to keep the controllers in step and therefore it has been of the utmost importance to replace all the induction motors.

The development of progressively timed signal systems is momentous since the inherent capacity of Philadelphia's narrow streets, normally only 26 to 34 feet wide, is extremely limited. The gains obtained in the vehicle-carrying ability of these streets through the effective progressive timing of signals are ample reward for the time consumed in developing time-space diagrams. In Philadelphia with its short and varying block lengths, this is no easy task, nor will all the required work of coordinating nearly 2,100 signalized intersections be accomplished in the near future.

5. *Use of Electronic Traffic Signal Controls:* The recent development and limited use of electronic traffic signal equipment herald the arrival of an invaluable aid to intersection control. Through the use of electronics the efficient movement of heavy volumes of traffic along major urban arteries frequently intersected by cross streets can be assured. Indeed, we are on the threshold of a new era in the adaptation of traffic signal controls to the *movement* of traffic. The keynote of this new era is flexibility and adaptability to the varying needs of traffic. Hitherto, flexibility in the use of traffic signal controls has been essentially limited to providing actuation at individual intersections where the inherent limitations of fixed-time equipment are no longer acceptable.

The development of volume-density traffic signal control equipment marks a major advance. Even more remarkable was the development of a master controller that not only establishes the signal cycle and the offsets of a whole system of signals, but also controls the minute-to-minute fluctuating demands of traffic. No longer should traffic officials be satisfied with half-way measures which at best are a compromise and which satisfy no single element of the traffic stream.

During the last three years, Philadelphia has enviously watched the development of electronic signal equipment and, to a minor extent and within the confines of its restricted signal budget, has purchased and installed limited quantities of volume-density equipment. To date volume-density equipment has been installed at fifteen complex major intersections and plans are underway to install similar equipment at ten additional intersections in the immediate future. In every instance the actual installation of this equipment has exceeded the most optimistic expectations of its proficiency. In all

cases the movement of the conflicting traffic streams has been materially expedited.

The availability of volume-density equipment has made possible the treatment of several extremely complex intersections which hitherto had defied successful signalization because of the complexity

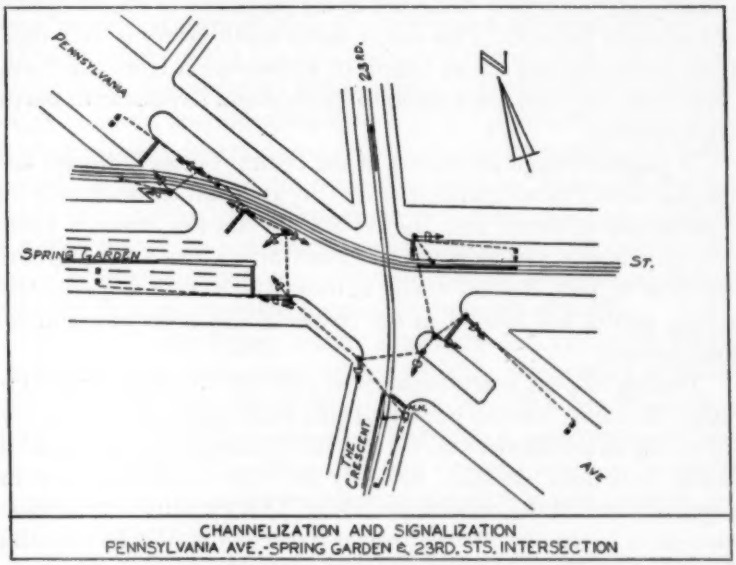


FIGURE 1.

of conflicting traffic movements. A case in point is the three-street intersection of Pennsylvania Avenue, Spring Garden and 23rd Streets, an intersection which has the additional complication of a crossing trolley movement emerging from and entering an underground tunnel. Figure 1 indicates the treatment given to that intersection.

The Broad Street Electronic System

The modernization of the outdated traffic signal controls on Broad Street represents the most significant step ever made by the traffic authorities of Philadelphia to increase the vehicular carrying ca-

pacity of a primary artery of that city. In order to understand fully the immensity of this problem perhaps a brief discussion of Broad Street's physical characteristics and its relationship to the basic street network is in order.

1. *Characteristics of Broad Street:* Broad Street has been frequently and accurately described as the backbone of Philadelphia's entire street network. This major north-south artery is 12.2 miles long, traversing the entire length of Philadelphia from the Naval Base at the city's southern limits to Cheltenham Avenue at its northern boundary.

It passes through the center of the central business district and loops around Philadelphia's massive City Hall, which sits astride the intersection of Broad and Market Streets. Market Street is Philadelphia's major east-west street. Broad Street has a curb-to-curb width of 69 feet. Narrow traffic islands, which serve as pedestrian refuge points, are located in the center of the street at all major intersections.

During off-peak hours Broad Street affords two lanes of travel in either direction. During peak hours the curb lanes are cleared, thus providing an additional lane for movement. In order to obtain additional peak-hour capacity, recently the city traffic engineer inaugurated use of the off-lane principle. This permits four lanes of movement in the direction of heavier travel and two in the opposing direction. Rubber traffic cones are used to indicate and separate the opposing movements. This operation has met with great success.

Broad Street was originally developed as the city's major residential street and until the early 1900's was essentially a promenade street lined with expensive homes and imposing mansions. As elsewhere, however, the elegance of the past has long since given way to commercial development and now only the upper and lower limits of the street can be classified as residential.

Although several of these commercial areas overlap, there are roughly ten separate and individual areas of business development, including the extended central business district. These areas are clustered along Broad Street at its intersections with major cross streets. Throughout its extensive course Broad Street is intersected by some 110 cross streets, and some 102 intersections are controlled by traffic signals. Approximately every fifth street is a major cross

street bearing considerable volumes of crossing and interchanging traffic.

2. *Installation of Interconnection:* In the early 1930's recognition of the necessity for affording through-movement along Broad Street resulted in the installation of an interconnected system of traffic controls. This system, the latest and most up-to-date at the time, permitted through time clock selection the establishment of different offsets of the fixed, single-length signal cycle. These predetermined offsets favored the direction of heavier movement during peak hours, thus affording some degree of progressive movement. During off-peak hours, however, a compromise setting was maintained, favoring neither direction of movement. The result was not particularly satisfactory. Through the years following its installation the efficiency of the now antiquated system constantly declined because of increasing volumes of traffic and the non-adaptability of the fixed-time system to the fluctuating demands of traffic.

3. *The Traffic Stream and its Requirements:* The traffic stream on Broad Street is composed of innumerable overlapping segments of traffic which make use of Broad Street for only a few blocks of its length. Only a minor portion of the traffic stream continues over its entire length. This situation is not unusual along urban traffic arteries which tap major intersecting streets and pass through successive commercial areas.

These traffic increments and subsequent decrements compose over 90 percent of Broad Street's total traffic stream, with less than ten percent of the vehicles traversing more than four miles of its length. Under such circumstances it is understandable why this street carries constantly fluctuating volumes of traffic. At one moment a certain segment of Broad Street has such heavy traffic as to require a 70-second cycle to allow for its efficient passage. Minutes later the volumes measurably decline and there is an immediate need for a shorter cycle permitting a somewhat higher overall speed. The fixed-time characteristics of the older interconnected system would not permit such a required variation in signal cycle.

It can be accurately stated that today Broad Street carries nothing but a series of successive peak movements, thus requiring constantly changing signal operations. In addition to the constantly fluctuating volumes in a single direction, it is not unusual for a heavy volume

in one direction to decrease sharply in a matter of minutes and for the opposing lighter volume of traffic to surge suddenly upward and soon exceed it.

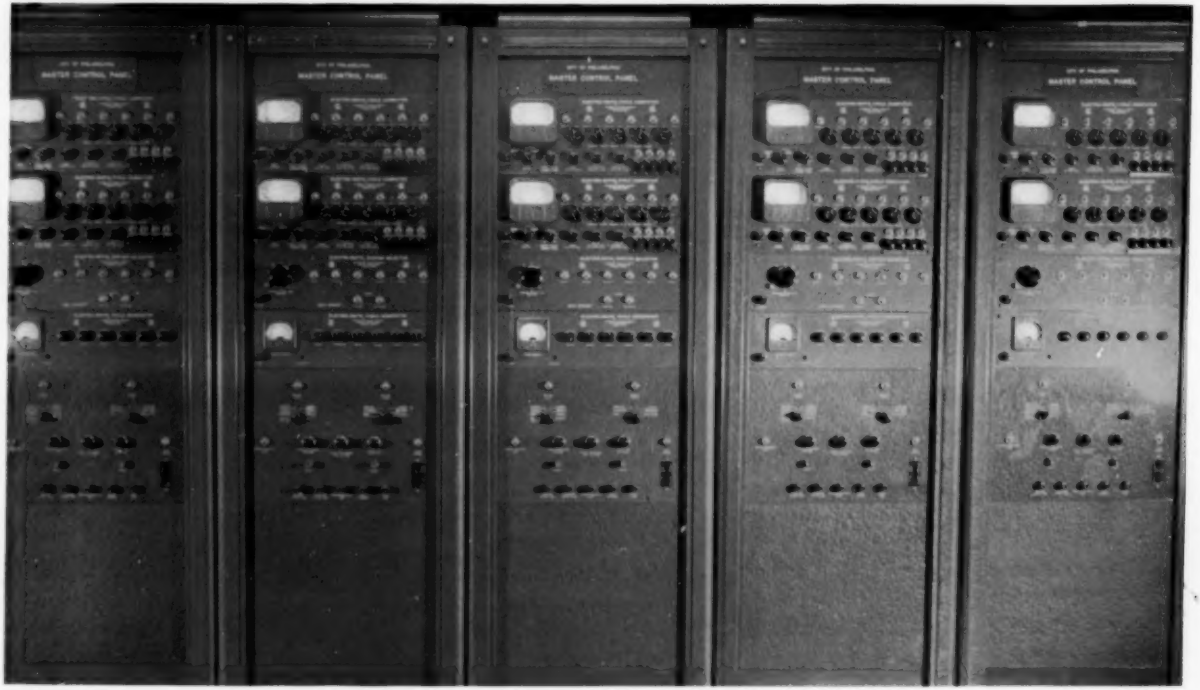
This phenomenon necessitated the provision of preferential signal operation, permitting offset treatment to accommodate the changing traffic requirements. Similarly, cycle length selection was essential to properly accommodate the ever varying traffic volumes.

Thus, the key to providing for the efficient use of Broad Street's limited traffic carrying facilities was the installation of a *flexible* system of traffic controls. Only through the provisions of flexible traffic controls could Broad Street's fluctuating traffic pattern be successfully matched to assure the efficient use of both Broad Street and its important intersecting traffic carriers. Another factor clearly indicated the advisability of complete modernization at this time. The majority of the traffic signal equipment along Broad Street was installed between 1923 and 1925 and its expected useful life has long since been exceeded. Various component parts were not only due for replacement, but the ever-increasing frequency of cable shorts, motor failures and falling out-of-step of the interconnected controllers forewarned of the necessity for a major overhauling of the entire system. A detailed analysis of the costs of replacing the time-worn equipment was made.

An estimate was also made of the cost for its replacement with electronic control equipment. A major item involved in either case was replacement of the interconnecting cable. The comparative estimates indicated that, for an additional cost of approximately 50 percent, a completely flexible electronic system could be installed. Therefore, it was not difficult to conclude that it would be unwise to consider the replacement of the worn-out equipment with even the most comprehensive fixed-time controls, since at best such a procedure would result in only minor improvements to the traffic flow.

The final hurdle was cleared when a thorough study of budget appropriations and overall city-wide signal requirements indicated that it would be economically feasible to purchase the necessary electronic controls and proceed with the modification of the system.

4. *General Operation of the Electronic System:* The basic concept of the electronic traffic signal system which has now been installed on South Broad Street and which is being extended north-



Master Control Panels, Broad Street, Philadelphia.

North Broad Street in Philadelphia, looking North.

ward, is to provide traffic on Broad Street with every possible second of green or passage time. This is accomplished through a master control which coordinates a series of interconnected semi-actuated dispatchers located at the intersecting streets. Use is made of a system of such control provided by a signal manufacturer at Norwalk, Conn.

Previously, four similar but more limited systems have been installed in other cities; Los Angeles has a twenty-five-intersection system, while New Orleans, Baltimore and Vallejo, California, are using much smaller systems. Since general knowledge of the method of operation of such systems is not prevalent, details of the operation of the new Broad Street System will be outlined.

The system is technically referred to as a "traffic actuated cycle and offset selector system." In simplest terms the Broad Street electronic system consists of a series of local signalized installations interconnected with each other and to a central control mechanism by cable. The system has a basic background cycle established by the densities of traffic on Broad Street.

Through interconnection and appropriate lead time settings, progressive movement is provided on Broad Street. The master control located in the basement of City Hall Annex regulates and coordinates the movement of traffic through each of the signalized intersections in the system. This electronic nerve-center performs the following basic functions:

It computes the best cycle length for both north and south movement on Broad Street. Impulses from traffic volume detectors located on Broad Street are received and determine the best cycle length to move the current traffic density.

It evaluates the two separate traffic cycle length requirements for both the north and south movements, and automatically selects and places in operation the most efficient cycle for the combined movement.

When the traffic movement is unusually heavy and only in one direction, it favors that movement.

Through a resynchronization unit, it provides synchronization of the local controllers once during each background cycle.

5. *Special Characteristics of the System:* The local controller at each signalized intersection within the system is of the semi-actuated

type. Vehicle detectors are located on each intersecting side street on its approach to Broad Street. This provides an indication to the local controller of the traffic requirements of the side street. Since the local controllers are interconnected, the signal changes resulting from side street actuation are so controlled as to minimize interference to the through-movement on Broad Street. In other words, upon actuation the green signal will only be given to the side street at such time as not to interfere with the established through-movement on Broad Street. Actuation by a single vehicle only allots a minimum portion of the traffic signal cycle to the side street. Subsequent actuations extend the minimum time to a pre-established maximum period. This assures continuity to the through-movement on Broad Street.

Because of Broad Street's width and heavy pedestrian crossing requirements, pedestrian push buttons have been provided at all major intersections. These pedestrian actuators are not required during daylight and early evening hours when vehicular movement is constant; however, they are necessary to provide for the safe crossing of Broad Street by pedestrians during the hours of infrequent vehicular actuation.

As previously indicated, the length of the Broad Street signal cycle is established by the master control, as determined by the detected vehicle densities on Broad Street. The cycle selectors increase or decrease the cycle length in accordance with traffic volumes. A choice of six possible cycle lengths is provided. Variations in traffic densities of approximately 25 percent cause the cycle length to jump to the next higher or lower setting.

The master control also regulates the direction of traffic to be favored. The automatic selection of cycle length and offset is accomplished by using two cycle selectors each evaluating traffic densities in a single direction. These cycle selectors are connected to an offset selector which evaluates the requirements and decides upon the most efficient cycle length and offset. In all cases the offset selector chooses the longer of the two cycles called for by the cycle selectors. When the two cycle selectors call for the same cycle length or for cycle lengths only one position apart the offset selector then retains an average offset pattern which is best for both directions. However, when the cycle selector units are two or more cycles apart, the offset

selector gives preference to the offset favoring the direction of heavier traffic.

The master control permits a total of five different direction settings or offsets. These settings are: (1) favoring inbound, (2) favoring outbound, (3) average by-directional, (4) simultaneous signal operation, and (5) free non-coordinated movement. The latter two settings are only responsive during periods of either extremely high or low traffic volumes, respectively. The free operation minimizes delays to cross street movement when overall traffic is so light that coordination can be dispensed with. Likewise, when unusual events produce extremely high traffic densities, the simultaneous operation expedites movement and eases the traffic backlog.

6. *Extent and Success of the System:* The South Broad Street System, extending 2.4 miles from Oregon Avenue to Chestnut Street, started operation on October 5, 1955. The system covers thirty consecutive signalized intersections and traverses areas of varying traffic generation and density. The installation has fully met all prior expectations. The innumerable intersection delays previously experienced at all hours along South Broad Street have all but disappeared. Traffic movement along Broad Street has been materially expedited. Even when the demands of side street traffic effect an interruption to the Broad Street movement, it is only for that minimum length of time required for the crossing traffic.

The electronic controls do, indeed, provide a truly flexible system. They allot every available second of time to the Broad Street movement and yet permit adequate time for crosstown traffic and pedestrian movement. This is accomplished without interfering with the signal pattern for progressive movement on Broad Street establishment by the master control.

The Broad Street electronic system is currently being extended to North Broad Street. Movement on North Broad Street will eventually be controlled by three successive systems. The first and second systems are now being installed and will add 4.7 miles to the present South Broad Street System. The first system will extend from Arch Street to Huntington Street, covering twenty-six intersections, while the second system will extend from Lehigh Avenue to Belfield Avenue and cover twenty-one intersections. Eventually, the second North Street system will be extended an additional nine in-

tersections, a distance of 1.3 miles. Upon total completion the entire Broad Street system will cover 8.4 miles and eighty-five signalized intersections. The entire cost of this complete revision of the existing fixed-time interconnected system will approximate $285,000.

7. *Future Requirements:* Broad Street is only one of several arteries in Philadelphia requiring the application of flexible signal control. Other locations high on the list for similar treatment by electronic signal controls are such essential arteries as West Market Street, Vine Street and Hunting Park Avenue.

Today's traffic demands require that full use be made of flexible traffic controls to assure that maximum efficiency is obtained from our restricted streets and limited traffic lanes. No longer are fixed-time signal controls satisfactory to handle increasing traffic volumes with fluctuating characteristics.

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